W. B. No. 614

U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 45, No. 3

MARCH, 1917

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

MARCH, 1917.

CONTENTS.

NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the Editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for the illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

VOL. 45, No. 3.
W. B. No. 614.

MARCH, 1917.

CLOSED MAY 3, 1917
ISSUED JUNE 1, 1917

INTRODUCTION.

As explained in this introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS TO THE MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Beginning August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology*.—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology*.—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere*.

SECTION 4.—*Rivers and floods*.

SECTION 5.—*Seismology*.—Results of observations by Weather Bureau observers and others as reported to the Washington office.

SECTION 6.—*Bibliography*.—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month*.—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1915. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but *all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.*

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belén College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

CORRIGENDUM.

REVIEW, *February, 1917:*
Page 81, column 2, table of average and accumulated departures, etc., fourth column opposite "Missouri Valley": *for* 2.68 *read* 0.27.

SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING MARCH, 1917.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Apr. 27, 1917.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1917, **45** : 2.

The monthly means and departures from normal values in Table 1 show that direct solar radiation averaged below its normal intensity at Washington, D. C., and very close to its normal intensity at the other three stations.

At 10 a. m of March 23 an intensity of 1.66 calories per square centimeter of normal surface was measured at Santa Fe, N. Mex., and at noon of the same day an intensity of 1.56 calories was measured at Lincoln, Nebr. These are the highest intensities ever measured at these stations in March.

Table 3 shows a deficiency of about 5 per cent in the total radiation for the month at Washington and Madison, and very close to the normal amount at Lincoln.

On account of unfavorable atmospheric conditions, due in some cases to the presence of local smoke, only two series of observations permit of extrapolation to zero air mass. These, as shown in Table 4, give average values of the solar constant.

TABLE 1.—*Solar radiation intensities during March, 1917.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.0°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Mar. 6	......	1.28	......	......	......	......	......	......	......	......
7	......	1.22	1.10	0.91	0.87	0.79	0.69	0.64	0.59	0.55
10	......	0.98	0.88	0.84	0.80	0.70	0.64	0.59	......	......
19	......	1.23	1.02	......	0.89	0.76	0.73	......	......	......
22	......	1.13	0.95	0.76	0.73	......	......	......	......	......
24	......	1.26	......	......	......	......	......	......	......	......
28	1.49	1.40	1.31	1.19	1.11	1.04	0.97	0.91	0.86	0.82
30	1.54	1.34	1.18	1.07	0.96	0.87	0.79	0.72	0.65	......
Monthly means	**(1.52)**	**1.23**	**1.07**	**0.95**	**0.89**	**0.83**	**0.76**	**0.72**	**0.70**	**(0.68)**
Departure from 9-year normal	......	**−0.07**	**−0.09**	**−0.11**	**−0.07**	**−0.04**	**−0.04**	**−0.04**	**−0.05**	**−0.03**
P. M.										
Mar. 6	......	1.28	1.15	1.04	0.92	0.84	0.80	0.77	0.76	0.72
7	......	1.23	1.05	......	......	......	......	......	......	......
8	......	......	1.16	1.02	0.94	0.85	0.78	0.72	0.66	......
15	......	......	1.24	1.10	0.99	......	......	......	......	......
19	......	1.27	1.05	0.92	0.81	0.68	0.62	0.58	0.53	0.48
22	......	1.16	1.04	0.92	0.85	......	......	......	......	......
24	......	1.22	0.97	0.73	0.69	0.67	0.63	0.59	0.56	......
25	......	1.24	1.01	......	......	......	......	......	......	......
28	......	1.36	1.27	1.18	1.09	1.00	0.92	0.85	0.80	0.77
30	......	1.36	1.22	1.12	1.04	0.96	0.91	0.89	......	......
Monthly means	......	**1.26**	**1.12**	**1.00**	**0.92**	**0.83**	**0.78**	**0.73**	**0.66**	**0.66**
Departure from 9-year normal	......	**−0.04**	**−0.03**	**−0.03**	**−0.03**	**−0.04**	**−0.03**	**±0.00**	**−0.02**	**+0.01**

TABLE 1.—*Solar radiation intensities during March, 1917*—Continued.

Madison, Wis.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.0°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Mar. 1	......	1.58	1.49	1.39	1.34	1.30	1.23	1.17	1.12	1.06
5	......	......	......	......	......	1.24	1.16	1.08	......	......
15	......	1.40	1.30	1.22	1.16	1.10	1.00	......	......	......
20	......	1.41	1.28	1.20	1.12	1.02	0.94	......	......	......
24	......	1.39	1.24	1.17	1.13	1.07	1.02	......	......	......
Monthly means	......	**1.44**	**1.33**	**1.24**	**1.19**	**1.15**	**1.07**	**(1.12)**	**(1.12)**	**(1.06)**
Departure from 7-year normal	......	**±0.00**	**−0.01**	**−0.03**	**−0.02**	**+0.01**	**±0.00**	**+0.05**	**+0.14**	**+0.08**
P. M.										
Mar. 1	......	1.56	1.50	1.42	1.34	1.26	......	......	......	......
2	......	......	1.31	1.14	0.99	......	......	......	......	......
20	......	......	1.36	1.28	1.17	......	......	......	......	......
21	......	......	1.41	......	1.26	......	......	......	......	......
24	......	1.36	1.21	1.08	0.99	......	......	......	......	......
Monthly means	......	**(1.46)**	**1.36**	**1.23**	**1.15**	**(1.26)**	......	......	......	......
Departure from 7-year normal	......	**+0.04**	**±0.00**	**−0.05**	**−0.06**	**+0.03**	......	......	......	......

Lincoln, Nebr.

A. M.										
Mar. 3	......	1.53	......	......	......	......	......	......	......	......
8	......	......	1.42	1.24	1.23	1.02	......	......	......	......
9	......	......	......	......	......	1.01	0.88	......	......	......
14	......	1.44	1.29	1.16	0.99	0.92	0.88	0.84	......	......
17	......	......	......	......	1.13	1.09	1.04	......	1.00	......
19	......	1.47	1.24	......	0.94	......	......	......	......	......
22	......	1.14	......	......	......	......	......	......	......	......
23	......	1.52	......	......	......	......	......	......	......	......
27	......	1.52	1.48	1.23	1.17	1.10	......	......	......	......
Monthly means	......	**1.44**	**1.36**	**1.21**	**1.09**	**1.03**	**0.93**	**(0.84)**	**(1.00)**	......
Departure from 2-year normal	......	**+0.02**	**±0.00**	**−0.08**	**−0.05**	**−0.01**	**+0.03**	**−0.03**	**−0.01**	......
P. M.										
Mar. 3	......	1.55	......	......	......	......	......	......	......	......
8	......	......	......	......	1.24	1.17	......	......	......	......
14	......	1.46	......	......	......	......	......	......	......	......
18	......	1.43	1.39	1.32	1.23	1.14	1.07	1.02	0.96	......
20	......	1.38	......	......	......	......	......	......	......	......
21	......	1.44	1.32	1.20	1.12	......	......	......	......	......
23	......	1.54	......	......	......	......	......	......	......	......
24	......	1.38	1.31	1.20	......	......	......	......	......	......
28	......	1.45	1.34	1.25	1.17	1.08	1.02	0.97	0.92	......
29	......	1.43	1.20	1.20	1.08	0.99	0.95	......	0.84	......
Monthly means	......	**1.45**	**1.31**	**1.23**	**1.17**	**1.10**	**1.01**	**(1.00)**	**0.91**	......
Departure from 2-year normal	......	**+0.02**	**±0.00**	**+0.01**	**+0.03**	**+0.04**	**+0.03**	**+0.08**	**+0.05**	......

TABLE 1.—*Solar radiation intensities during March, 1917*—Continued.

Santa Fe, N. Mex.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.0°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Mar. 8		1.56				1.42				
12					1.28	1.18				
14		1.50								
23	1.65	1.65								
24		1.56	1.48	1.42	1.36	1.30				
27	1.54	1.51	1.47	1.43	1.35	1.28	1.21	1.15		
28	1.56	1.50		1.38	1.34	1.30				
Monthly means	**1.58**	**1.55**	**(1.48)**	**1.41**	**1.33**	**1.30**	**(1.21)**	**(1.15)**		
Departure from 5-year normal	**±0.00**	**+0.03**	**+0.01**	**+0.01**	**−0.01**	**+0.03**	**−0.01**	**−0.01**		
P. M.										
Mar. 8		1.53	1.49	1.42	1.33	1.25				
14		1.59	1.45	1.36	1.28	1.20				
23		1.56	1.51							
24			1.45	1.36	1.29	1.23				
27		1.33	1.19	1.17						
28		1.30	1.22	1.13	1.08	1.01	0.96			
Monthly means		**1.46**	**1.38**	**1.29**	**1.24**	**1.17**	**(0.96)**			

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*
Mar. 6	1.60	2.49	Mar. 1	0.86	1.88	Mar. 3	1.68	1.52	Mar. 8	1.68	1.96
7	3.00	3.63	2	1.37	1.88	8	2.49	2.49	12	2.06	2.16
8	7.29	3.15	5	0.74	1.68	9	2.49	3.00	14	1.88	1.68
10	3.81	5.16	15	2.26	3.00	14	2.74	2.74	23	1.52	1.88
15	4.75	3.45	20	3.30	3.81	17	2.36	2.74	24	2.36	5.16
19	1.60	3.00	21	3.30	3.15	18	2.06	2.87	27	2.36	1.68
22	4.95	5.36	24	3.63	4.57	19	3.99	3.63	28	1.52	1.96
24	5.79	4.37				20	3.45	3.81			
25	4.37	4.37				21	3.63	3.15			
28	2.62	2.87				22	4.57	4.95			
30	3.15	4.37				23	3.45	4.37			
						24	2.74	2.62			
						27	2.26	1.78			
						28	2.49	3.81			
						29	3.15	2.06			

TABLE 3.—*Daily totals and departures of solar and sky radiation during March, 1917.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	calories.	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*
Mar. 1	73	441	356	−222	144	17	−222	144	17
2	79	412	321	−220	111	−21	−442	255	−4
3	65	425	409	−237	120	65	−679	375	61
4	62	442	426	−244	134	80	−923	509	141
5	313	411	312	4	99	−36	−919	608	105
6	469	288	351	157	−27	2	−762	581	107
7	472	105	240	157	−213	−111	−605	368	−4
8	302	101	423	−16	−220	71	−621	148	67
9	292	269	354	−29	−54	0	−650	94	67
10	430	124	383	106	−202	28	−544	−108	95

TABLE 3.—*Daily totals and departures of solar and sky radiation during March, 1917*—Continued.

Day of month.	Daily totals.			Departures from normal.			Excess of deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	calories.	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*
Mar. 11	168	127	349	−158	−201	−8	−702	−309	87
12	420	286	35	91	−45	−323	−611	−354	−236
13	84	64	123	−248	−270	−237	−859	−624	−473
14	38	358	459	−297	21	98	−1,156	−603	−307
15	455	432	168	117	93	−195	−1,039	−510	−579
16	426	78	93	85	−264	−271	−954	−774	−841
17	119	441	398	−225	96	32	−1,179	−678	−809
18	305	528	456	−42	180	89	−1,221	−498	−720
19	538	437	412	188	87	44	−1,033	−411	−676
20	386	493	432	33	140	62	−1,000	−271	−614
Decade departure							**− 456**	**−163**	**−709**
21	47	469	455	−309	113	84	−1,309	−158	−530
22	483	453	408	124	95	36	−1,185	−63	−494
23	259	152	484	−103	−209	111	−1,288	−272	−383
24	480	523	477	115	159	103	−1,173	−113	−280
25	528	362	384	160	−4	9	−1,013	−117	−271
26	474	131	326	103	−238	−50	−910	−355	−321
27	60	279	501	−314	−92	124	−1,224	−447	−197
28	598	420	483	221	46	105	−1,003	−401	−92
29	471	395	493	91	19	114	−912	−382	22
30	607	419	446	225	40	66	−687	−342	88
31	508	176	332	123	−205	−49	−564	−547	39
Decade departure							**+436**	**−276**	**653**
Excess or deficiency since first of year. calories							**−1,357**	**+1,538**	**−368**
Excess or deficiency since first of year. Per cent							**−5.9**	**+6.8**	**−1.4**

TABLE 4.—*Solar radiation intensities for zenithal sun reduced to mean solar distance of the earth, and approximate values of the solar constant.*

[Gram-calories per minute per square centimeter of normal surface.]

Station.	Date.	Radiation intensity.		Solar constant.
		m = 1	m = 0	
	1917.	*calories.*	*calories.*	*calories.*
Madison, Wis.	Mar. 1, p. m.	1.65	1.85	1.93
Lincoln, Nebr.	28, p. m.	1.56	1.82	1.93

Skylight polarization measurements at Washington give a mean of 60 per cent, and a maximum of 65 per cent on the 28th. These are slightly below average March values for Washington.

METEOROLOGICAL OBSERVATIONS BY AN AERONAUT.[1]

[*Reprinted from* Nature, London, Mar. 22, 1917, 99: 73.]

Lieut. Douglas, Royal Flying Corps, gives some details of his experience during his ascents among the clouds in northern France. He finds stratus cloud most frequently in anticyclones and round their eastern and northern borders. The top in such cases is very flat and even, and an inversion of temperature is met with at the upper surface. The lowest temperature is generally at the top of the cloud, but is occasionally met with a little lower. If cumuli attain sufficient height they develop into thunderstorms, but at least 6,000 feet (1,828.8 m.) from top to bottom is required for this to happen, and on all occasions in 1916 when thunder developed the height was not less than 10,000 feet (3,048 m.). Mr. Douglas states that cirrus and cirro-stratus almost certainly consist of thin snow.

[1] Journal, Scott. meteorol. soc., No. 33.

SECTION II.—GENERAL METEOROLOGY.

HAIL IN THE UNITED STATES.[1]

By ALFRED J. HENRY, Professor of Meteorology.

[Dated: Weather Bureau; approved by Chief of Bureau, Mar. 29, 1917.]

The occurrence of hail at Weather Bureau stations is made a part of the record of precipitation, the principal object sought being to complete the record of precipitation in whatever form it may have occurred. While the printed record does not distinguish between a damaging and a harmless hailstorm, yet such distinction is made in the manuscript records and a very brief account of damaging hail is kept under the caption "Meteorological notes." These latter have not been printed and it is not possible, therefore, to compile statistics of damaging hailstorms except by the expenditure of a large amount of time and labor in examining the manuscript records. The compilation of hail statistics on which this paper is based was undertaken because of the immediate necessity for a knowledge of the approximate frequency of hail throughout the United States. The printed records will be found in the series of annual reports of the Chief of Weather Bureau (Annual Meteorological Summaries).

A previous attempt made in 1898 (MONTHLY WEATHER REVIEW, 1898, **26**: 546), was not wholly successful because the data then available were incomplete.

The phenomenon of hail is even more local in its distribution than precipitation, hence one of the great difficulties in determining its frequency over areas of considerable size.

Director A. Angot, of the French meteorological service, has stated[2] that about 1,000 stations would be necessary for an area of 4,050 square miles in order to study the distribution of hail in sufficient detail. Such distribution of stations, if uniformly made, would require *one station for every 4 square miles*, or in a State the size of Iowa, for example, nearly 14,000 stations.

The total number of records used in the preparation of the present paper and included in Table 1 is 167 for an area of 3,026,789 square miles, or, if uniformly distributed, *one station for every 18,124 square miles*, or one station for an area the size of New Hampshire and Vermont.

The actual distribution for certain regions is, however, better than the above average. Thus, for example, Iowa, with an area of 56,147 square miles, has six stations within its borders and one separated from it by the Missouri River only, a total of seven, or one for each 8,021 square miles. Five of these stations, however, are massed in the river valleys which bound the State on the east and the west, respectively.

The annual frequency of hail in Iowa, as shown in Table 1, is:

Stations.	Hailstorms.
Sioux City	3.3
Omaha (Nebr.)	2.8
Des Moines	3.8
Charles City	2.8
Dubuque	2.8
Davenport	2.9
Keokuk	2.4

[1] Accompanied by five figures forming charts XLV-28 to XLV-32, inclusive.
[2] See this REVIEW, March, 1914, 42: 167, column 1, last paragraph.

The above figures mean simply that, on the average, hail falls about three times each season. While the figures give no information as to the intensity of the storms, it is a matter of common experience that many hailstorms are harmless and that damaging hailstorms are not numerous, at least in many portions of the country.

One hail insurance company of Iowa states that in the last 24 years it has paid a total of $1,860,633.04 in hail losses, or an average of $77,526.40 per year. Naturally the losses in some years are greater than in others. The losses sustained by this one company for 1915 were $225,219 and in 1916 were $135,204. From these figures there is no way of arriving at the number of acres damaged or the extent of the damage, whether total or only partial in each case. What is needed is an accurate statement of the number and extent of damaging hailstorms in each quarter section of the State for at least 10 years. The magnitude of the problem is thus apparent.

It is clear from the figures of Table 1 that the frequency of hail as a meteorological phenomenon varies sometimes within the limits of a single State; thus the frequency of hail is greater in western Kansas and Nebraska than in the eastern portions of the same States, and according to Section Director George M. Chappel, of Des Moines, Iowa, mutual hail insurance companies of that State charge a higher rate for hail risks in northern than in southern counties. The average cost of $1,000 hail insurance for a period of 5 years according to a prominent company was for northern counties $18.10 and for southern counties $17.70. This difference is not great, and more detailed data might easily change the ratio, since there is seemingly no reason for a greater frequency in northern than in southern counties, but it would not be surprising to find a diminution of storms in an eastward direction, since the region of infrequent storms lies east of the Mississippi River. In Kansas hail insurance costs as much as 10 per cent in the extreme northwestern counties and about 4 per cent in extreme eastern counties.

Geographic distribution.

The chart of annual hail frequency shows that the region of most frequent occurrence, four or more storms per year, is in southeastern Wyoming and eastward therefrom, including the western portions of Kansas, Nebraska, and Oklahoma. Adjoining this region of maximum frequency, especially to the eastward, the average number of storms per annum decreases to three. Roughly speaking, the region of the occurrence of at least three hail storms on an average per annum includes practically all of South Dakota, Nebraska, Kansas, the western and central portions of Iowa, northwestern third of Missouri, all of Colorado, and the southeastern portion of Wyoming. These two districts having three and four storms per annum may be considered as the chief hail regions of the United States. East of the Mississippi the annual average is two storms or less per annum. A second region of hail frequency comprises a portion of southwestern Montana and southern Idaho and the mountain districts of northern New Mexico and northern Arizona. (See fig. 5, XLV-32.) The occurrence of hail in

the foregoing named regions is a phenomenon of late Spring and Summer. Winter hail is frequent along the Pacific coast from San Francisco northward, particularly at the mouth of the Columbia River. Hail also occurs in Winter, but rather infrequently in the East Gulf States, extreme northeast Texas, northern Louisiana, northern Mississippi, northern Alabama, northern Georgia, and southwestern North Carolina. In general, there is an absence of hail at all seasons along the Gulf and Atlantic coasts.

Seasonal distribution.

Hail in the United States is, in general, a phenomenon of the warm season, the only notable exception being along the immediate Pacific coast from San Francisco northward. On that strip of coast hail occurs chiefly from November to March, a season that is substantially the same as that of the rains in that part of the United States.

According to District Forecasters Beals and Willson of Portland, Oreg., and San Francisco, Cal., respectively, the hail of Winter and Spring on the Pacific coast is soft hail or graupel. True hail, of sufficient size to injure crops, rarely occurs. Mr. Beals is able to recall the occurrence of but a single destructive hailstorm in Oregon in the 17 years of his residence in that State, and, likewise, Mr. Willson recalls a damaging hailstorm in California in September, 1916. In both States hail is associated with thunderstorms. The latter are not uncommon in Oregon and Washington, but are very rare in the lowlands of California, although they occur with some frequency on the higher mountains beyond the level of agricultural lands.

Hail also occurs infrequently, it is true, in the Gulf States during the cold season; the region of most frequent occurrence is, however, some distance inland from the coast, viz, in the hilly regions of northern Alabama, northern Georgia, and southwestern North Carolina, particularly. Winter hail in the United States occurs in connection with the movement of LOWS from the Pacific inland, and again when LOWS of whatever place of origin move across the Gulf States. (See fig. 4, XLV-31.)

In the warm season the occurrence of hail is very closely associated with thunderstorm and tornadic phenomena. The writer has pointed out elsewhere that tornadoes occur in Spring a short distance inland from the Gulf coast and that as the season progresses the region of greatest tornadic activity seems to spread northward over the Great Plains States. A development and movement closely paralleling that of tornadoes is observed in hail storms, the last-named are most frequent in Oklahoma in March, for example. As the season advances the region of greatest frequency is found to the northward in Kansas, and the month of greatest frequency is May instead of March. In western Kansas and southeastern Wyoming the month of greatest frequency is June. (See fig. 1, 2. XLV-29-30.)

Damage to crops by hail.

Practically no damage to agricultural crops by hail is possible in the Pacific Coast States and only small damage is possible in the Gulf States both by reason of the infrequency of the phenomenon and the absence of crops at the time of greatest frequency. In Kansas, Nebraska, South Dakota, western Iowa and northwestern Missouri, hail falls at a time when destruction of crops is possible.

Distribution of hail in general.

Hailstorms over both land and water occur most frequently in temperate latitudes, the belt of greatest frequency being between the 35th and the 60th parallels in both hemispheres. They are infrequent in the Tropics, especially over the lowlands. In Arctic and Antarctic regions while hail occurs more frequently than was once supposed, lack of precise observations makes it somewhat conjectural whether the hail reported is graupel or true hail.

The geographic distribution of hail and its destructive effects on crops have been studied in Europe in great detail.

Württemberg.—Dr. Anton Bühler, of Zurich, has discussed in great detail the damage by hail in Württemberg during the 60 years 1828–1887.[3] The number of hail days during the 60 years averaged 13 and ranged from a maximum of 28 days in 1852 to but 4 days in 1867 and 1879. The smallest superficial area damaged in any one year was 1,627 hectares (4,020 acres) and the greatest was 32,133.7 hectares (79,402 acres).

India.—Although records of hail frequency and damage in India are not available for so long a period as in some European countries, yet much valuable information has already been collected and is summarized in Indian Meteorological Memoirs, volume 6, from which the matter below has been abstracted.[4]

Hailstorms occur in India almost exclusively during the dry or northeast monsoon. In the first half of this period or during the cold weather, they are restricted to northwestern and central India and occur in connection with and during the passage of cyclonic storms across India.

The prevailing winds are of continental origin and the air is hence comparatively dry, more especially in Rajputana and Central India, where hailstorms chiefly occur. During the second half of the dry monsoon, or the hot-weather months, March, April, and May, hailstorms usually occur under different conditions from those which give rise to hailstorms in the cold weather and also occur chiefly in areas where these storms are of rare occurrence in the preceding cool months. Hailstorms in the hot-weather months invariably accompany thunderstorms or, as it would be more correct to state, they are severe local thunderstorms, the precipitation in part of the area occurring as hail.

Thunderstorms and hailstorms hence occur chiefly at the period when convective action is most vigorous. The conditions which accompany and appear to be essential to their formation are: High temperature, large diurnal range of temperature. The large ascensional movement necessary for the formation of hailstones appears to be provided either:

(1) By exaggerated hot-weather conditions in the open plains, giving rise to unusually vigorous convectional movement.

(2) By a strong, dry land current advancing seaward and passing under a sea current and forcing the latter upward.

(3) By air movement from the plains across lines of hills.

In the Assam Valley the Assam Hills, and the Cachar hailstorms appear to be the result of forced ascent of sea winds in hot weather, blowing across the Bengal coast into east and central Bengal and across the Assam Hills into Assam.

In Bengal they appear to be due chiefly to the second action, the dry, westerly winds of the Gangetic Plains working under and forcing upward the southerly sea winds prevailing in that area at the time.

Hailstorms rarely occur in India south of latitude 16°.

Cold-weather hailstorms in India.

The general inference suggested from the statistics of hail frequency is probably correct, viz, that hailstorms are most frequent in Central India and Rajputana, area through which the primary depressions of the cold-weather storms almost invariably pass and that they are much less frequent in the northwestern provinces to the north of their general line of movement and the central provinces to the south of it.

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[3] Die Hagelbeschädigungen in Württemberg. Stuttgart, 1890.

[4] Hailstorms in India during the period 1883-1897. J. *Eliot*, Meteorological Reporter to the Government of India. (Ind. Met'l. mem., v. 6.)

Hailstorms of the second class, viz, hot-weather or summer thunderstorms, occur chiefly during the hot-weather months of March, April, and May and in districts in which convectional air movement (or forced ascent) due to thermal action, is large and vigorous, and also generally where the lower air strata are comparatively damp, as is the case in the maritime provinces of Bengal, Bombay, and Madras and in the Assam River Valley.

THEORIES OF HAIL.

Many theories of the formation of hail have been advanced within the last 100 years and the subject has been discussed from a number of slightly different viewpoints. There appears to be unanimity of opinion upon the following:

(1) Hailstorms (in temperate latitudes at least) are almost invariably associated with thunderstorms in which a display of electrical action is a prominent feature. While this association is an intimate one there does not appear to be any relation such as cause and effect between the two phenomena.

In the United States the region of greatest thunderstorm frequency does not coincide with the region of greatest hail activity. This fact is strikingly illustrated by a comparison of the average number of days with hail and with thunderstorms at two points representing, respectively, the region of greatest hail frequency and the greatest thunderstorm frequency. In this connection see W. H. Alexander's paper in this REVIEW, 1915, **43**:322, for tables and charts of thunderstorm frequency. The two points selected are: For hail, Cheyenne, Wyo., and for thunderstorms, Montgomery, Ala.

In the table below will be found the average number of days with hail and thunderstorms, respectively, for these two places.

Average number of days with hail and with thunderstorms.

Montgomery, Ala.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Hail	0.1	0.2	0.2	0.4	0.1	0.3	0.1	0	0	0	0	0	1.4
Thunderstorms	1.6	2.7	3.8	4.4	7.3	11.5	11.4	10.1	6.4	1.1	1.4	0.7	62.4
Ratios	*1:16*	*1:13*	*1:19*	*1:11*	*1:73*	*1:38*	*1:114*	.....	.....	.....	.....	.....	*1:44*

Cheyenne, Wyo.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Hail	0	0	0.1	0.4	1.4	3.2	1.4	1.5	1.2	0.2	0	0	9.4
Thunderstorms	0	0	0.2	2.5	7.5	11.9	14.0	11.2	4.9	0.6	0	0	52.8
Ratios	.....	.....	*1:2*	*1:6*	*1:5*	*1:4*	*1:10*	*1:7*	*1:4*	*1:3*	.....	.....	*1:6*

At Montgomery, Ala., the period of maximum *hail* is in the months February, March, and April, with a second maximum in June; but the latter may be more apparent than real, due probably to the local distribution of hail. Statistics for other stations in Alabama (Table 1) show that there is practically no hail along the Gulf coast after May, but that with distance inland from the coast and the slight increase of elevation, in the northern part of the State, as at Birmingham, the season of maximum hail falls in April and May. At Jacksonville, Fla., the chief hail maximum falls in June, thus tending to confirm the secondary maximum in June at Montgomery, Ala.

The period of maximum *thunderstorm* activity at Montgomery, Ala., falls in the summer, June, July, and August, while hail ceases after July. The ratio of hail to thunderstorms is greatest in April, 1:11, and least in July, 1:114.

The ratios "hail to thunderstorms" given above for the two stations Montgomery and Cheyenne show that the ratio hail to thunderstorm is much greater in Cheyenne than in Montgomery and it also may be interpreted as emphasizing the infrequency of hail with thunderstorms in the Gulf States.

The director of the French meteorological service in a recent paper [5] states that the cause of the production of hail can not be seen in the electric manifestations that accompany it.

The view that all hailstorms are merely intense thunderstorms in which a part of the precipitation is in the solid form—enunciated first, I believe, by Eliot in discussing the hailstorms of India—has much to commend it.

(2) That a prerequisite to the formation of hail is an ascending current of sufficient strength to carry drops of water or small balls or bunches of moist snow upward into the colder air strata there to be frozen. There are several lines of argument in favor of the origin of hail in a strong ascensional current, viz:

(*a*) The constitution of hailstones—concentric layers of ice or of ice and snow of different texture—points to repeated condensations and freezings suggesting the existence of a strong ascensional current.

(*b*) The evidence of cumulo-nimbus clouds also strongly points toward the existence of a strong vertical uplift and the measured height of these clouds in the warm season provide further confirmation, if confirmation is necessary, of the fact that their summits extend well into the region of ice clouds.

(*c*) The tops of these clouds must therefore be chilled by expansion, by radiation, by evaporation into the dry air, and by their contact with the colder air strata. Whether the cloud particles will freeze on passing through the isotherm of 0°C. or whether they will pass into a state of "subcooling" is of course a matter of speculation; but in any event it seems clear that the origin of hail is to be found connected with the changes that are taking place within great cumulo-nimbi. Prof. William Ferrell held the view that a hailstorm is simply a tornado in which the ascending currents are so strong and reach up so high that raindrops are carried up into the cold regions above and there frozen into hail.

Hail is generally associated with tornadoes, yet the writer much doubts whether the fundamental conditions for the formation of a tornado are always present in a hailstorm. Rather it should be recognized that just as there are degrees of intensity in thunderstorm phenomena, so there must be degrees of intensity in the conditions that produce hail. It is a fact worthy of mention that the region of greatest thunderstorm frequency in the United States does not coincide with the region of greatest hail frequency. Hail occurs with greatest frequency in southeastern Wyoming and over the Plains region immediately to the eastward, also in elevated regions of New Mexico and Arizona. It is conceivable that an ascending air current starting from the elevated regions of New Mexico and Arizona will not only be cooler initially, but will also sooner reach the isotherm of 0°C. than will an ascending current starting, say, in Florida or the Southeastern States where thunderstorms during the summer months are of almost daily

[5] *A. Angot* in Compt. rend., Acad. agric. de France, 2 (1916), No. 31, pp. 912-913; *transl.* in this REVIEW, Dec., 1916, **44**:679.

occurrence. It also seems reasonable to suppose that an ascending current that originates, say, in the lee of the Rocky Mountains will require less initial ascensional energy to penetrate the colder upper strata than would be required in regions where the isotherm of 0°C. is found at a greater elevation. Kite and balloon observations made by the Weather Bureau at Mount Weather, Va., show that the isotherm of 0°C. is at its greatest altitude [6] in the months of July, August, and September.

Another reason for the absence of hail in the lower latitudes is the likelihood that even should hail occasionally form there, it will be melted before reaching the earth. Hail observed at great altitudes in the Tropics is invariably small.

It has been computed that a hailstone 6 millimeters (nearly a quarter of an inch) in diameter can not fall through the air at a speed greater than 5.42 meters per second. If then, the origin of the hail be placed at 5 kilometers—a not unusual altitude—a little more than nine minutes would be consumed in falling to the ground. There is ample reason to believe that at air temperatures which prevail during thunderstorms in lower latitudes, any hail which might be formed would probably be melted before it reached the surface of the earth.[7]

Elsewhere [8] the writer has expressed the opinion that thunderstorms in the Southeastern States are less violent than in the Northern States. The freedom from hail in the South seems to confirm the opinion heretofore expressed.

I have been assisted in the preparation of this paper by Mr. Bertrand W. Bailey of the River and Flood Division.

TABLE 1.—*Average number of days with hail, 1906–1915.*

Pacific Coast.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Washington.													
Tatoosh Island	0.4	0.6	0.5	0.5	0.1	0	0	0	0	0.7	1.9	0.9	5.6
North Head	1.4	0.8	1.1	0.9	0.1	0	0	0	0	0.3	0.9	0.6	6.1
Seattle	0	0	0.6	0.3	0.2	0.4	0	0	0.2	0.3	0.4	0.2	2.6
Tacoma	0.7	0.5	0.4	0.9	0.5	0	0	0	0.2	0.4	0.5	0.1	4.2
Spokane	0.0	0.1	0.7	0.7	1.0	0.7	0.2	0	0.3	0.1	0	0	3.8
Walla Walla	0.2	0	0.4	0.5	0.1	0	0	0	0	0.1	0.1	0	1.4
Oregon.													
Portland	0	0.4	1.0	0.8	0.7	0.3	0	0	0.2	0.2	0.2	0.3	4.1
Baker City	0	0.1	0.1	0.3	0.5	0.9	0.5	0.1	0.3	0.1	0	0	2.9
Roseburg	0.1	0	0.6	0.4	0.2	0.3	0	0	0.1	0	0.1	0	1.8
California.													
Eureka	1.2	1.1	1.2	0.3	0.2	0	0	0	0	0	0.4	0.5	4.9
Mount Tamalpais	1.2	0.3	0.9	0	0.2	0	0	0	0	0	0.3	0.5	3.4
San Francisco	0.9	0.6	0.7	0	0	0	0	0	0	0	0.1	0.3	2.6
San Diego	0.1	0.2	0.5	0.3	0	0	0	0	0	0	0.2	0.3	1.6
Red Bluff	0.3	0.2	0.5	0	0.6	0.3	0	0	0	0	0	0.2	2.1
Sacramento	0.6	0.3	0.2	0	0	0	0	0	0	0	0	0	1.1
Fresno	0.2	0.4	0.4	0.2	0.1	0	0	0	0	0	0.1	0	1.4
San Luis Obispo	0.3	0.4	0.3	0	0	0	0	0	0.1	0	0	0.1	1.2
Los Angeles	0.1	0.1	0.3	0	0	0	0	0	0	0	0	0.1	0.6

[6] Bulletin, Mount Weather Observatory, 6: 179.

[7] See also in this connection R. Russell on "Hail," p. 133.

[8] *A. J. Henry.* Loss of life in the United States by lightning. Washington, 1901. 8°. p. 15, fig. (Weather Bureau bulletin No. 30.)

TABLE 1.—*Average number of days with hail, 1906–1915*—Continued.

Great Basin.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Idaho.													
Lewiston	0	0	0.3	0.3	0.3	0.1	0.3	0	0.2	0.1	0	0	1.6
Boise	0.1	0	0.3	0.6	0.9	0.4	0.1	0.1	0	0.2	0.2	0.1	3.0
Pocatello	0	0.3	0.6	0.8	0.9	1.1	0.6	0.4	0.6	0.1	0	0.2	5.6
Utah.													
Salt Lake City	0.1	0.2	0.4	0.2	0.7	0.4	0	0.2	0.2	0	0.2	0.1	2.7
Modena	0.1	0.1	0.3	0.7	0.9	0.5	0.4	0.7	0.3	0.1	0	0	4.1
Nevada.													
Reno	0	0	0.1	0.2	0.8	0.1	0.2	0.2	0.1	0.1	0.1	0	1.9
Tonapah	0	0.1	0	0	0.4	0	0.1	0.1	0.1	0	0	0	0.8
Winnemucca	0.1	0.1	0.1	0.1	0.3	0.4	0.1	0	0.1	0	0	0	1.3
Arizona.													
Flagstaff	0.1	0	0	0.3	0.2	0.4	1.5	1.2	0.9	0.3	0	0	4.9
Phoenix	0	0.4	0.3	0.2	0.1	0	0.1	0	0	0.1	0	0	1.2
Yuma	0	0	0.1	0	0	0	0	0	0	0	0	0	0.1

Rocky Mountains.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Montana.													
Kalispell	0	0	0	0	0.4	0.5	0.2	0.6	0.1	0.1	0	0	1.9
Havre	0	0	0	0.2	0.4	1.0	0.4	0.1	0	0	0	0	2.1
Helena	0	0	0	0.1	1.0	1.3	1.2	0.3	0.3	0.1	0.3	0	4.6
Miles City	0	0	0.1	0	0.6	0.5	0.2	0.5	0	0	0	0	1.9
Wyoming.													
Yellowstone Park	0	0	0	0	0.5	1.5	0.8	1.1	0.4	0.1	0	0	4.4
Lander	0	0	0.2	0.6	0.1	0.4	0.1	0.3	0	0	0	0	1.7
Cheyenne	0	0	0.1	0.4	1.4	3.2	1.4	1.5	1.2	0.2	0	0	9.4
Colorado.													
Grand Junction	0	0.1	0.3	0.8	0.5	0.6	0.1	0	0.4	0	0.1	0	2.9
Denver	0	0	0	0.3	0.8	1.2	0.3	0.3	0.2	0	0	0	3.1
Pueblo	0	0	0.1	0.7	0.6	1.1	0.6	0.2	0.1	0	0	0	3.4
New Mexico.													
Santa Fe	0.1	0	0.7	0.8	1.1	1.0	1.0	0.2	0.3	0.6	0	0	5.8
Roswell	0	0.1	0	0.5	0.8	0.2	0	0	0.1	0	0	0	1.7

Plains.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
North Dakota.													
Williston	0	0	0	0	0.5	0.1	0.5	0.5	0.3	0.1	0	0	2.0
Devils Lake	0	0	0	0.1	0.5	0.4	0.6	0.1	0.1	0.1	0	0	1.9
Bismarck	0	0	0	0.4	0.6	0.7	0.4	0.3	0	0	0	0	2.4
South Dakota.													
Rapid City	0	0	0	0.1	0.4	0.6	1.2	0.5	0.2	0	0	0	3.0
Pierre	0	0	0	0.3	0.4	0.8	0.4	0.5	0.1	0.1	0	0	2.6
Huron	0	0	0	0.3	0.9	1.0	0.6	0.1	0.3	0.1	0	0	3.3
Yankton	0	0	0.2	0.4	0.8	0.6	0.7	0.3	0.2	0	0	0	3.2
Nebraska.													
Valentine	0.2	0.1	0.1	0.2	0.8	0.3	0.7	0.6	0.2	0.1	0.1	0	3.4
North Platte	0	0.2	0.1	0.5	1.0	0.5	0.9	0.7	0.1	0	0	0	4.0
Omaha	0	0	0.1	0.9	0.8	0.2	0.3	0.1	0.3	0	0.1	0	2.8
Lincoln	0	0	0.5	0.7	0.7	0.5	0.4	0.3	0.2	0	0.2	0	3.5
Kansas.													
Dodge City	0	0	0.2	0.6	0.7	1.4	0.3	0.5	0.1	0.4	0.3	0	4.5
Topeka	0.2	0.1	0.3	0.5	0.8	0.5	0.1	0.1	0.4	0	0	0	3.0
Concordia	0	0	0	0.6	1.1	0.5	0.4	0.1	0.4	0.4	0.1	0	3.6
Iola	0	0.1	0.5	1.0	0.7	0.5	0	0	0.1	0.2	0.2	0.1	3.4
Wichita	0	0.2	0.3	1.2	1.3	0.5	0	0	0.1	0	0.1	0	3.7
Oklahoma.													
Oklahoma City	0	0.2	0.8	1.5	1.0	0.3	0	0	0.1	0.1	0.1	0	4.1

TABLE 1.—*Average number of days with hail, 1906-1915*—Continued.

Mississippi Valley.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Minnesota.													
Duluth	0	0	0	0.1	0.7	0.2	0.6	0.1	0.1	0.2	0.1	0	2.1
Moorhead	0	0	0	0	0.2	0.3	0.1	0.5	0.1	0	0	0	1.2
St. Paul	0	0	0	0.2	0.4	0.3	0.1	0.2	0.2	0	0	0	1.4
Iowa.													
Sioux City	0	0.1	0	0.7	0.9	0.7	0.4	0.2	0.3	0	0	0	3.3
Charles City	0	0	0.1	0.2	0.9	0.7	0.3	0.3	0.1	0.2	0	0	2.8
Dubuque	0	0	0.2	0.6	0.6	0.3	0.2	0.3	0.2	0.1	0.3	0	2.8
Des Moines	0	0	0.3	0.6	1.2	0.3	0.3	0.2	0.5	0.4	0	0	3.8
Davenport	0	0.1	0.2	0.9	0.6	0.6	0.1	0.1	0.2	0	0.1	0	2.9
Keokuk	0	0	0.4	0.4	0.8	0	0.3	0.3	0	0.1	0.1	0	2.4
Illinois.													
Chicago	0	0	0.2	0.5	0.2	0.5	0.2	0.3	0	0	0	0.1	2.0
Peoria	0	0.1	0.4	0.5	0.4	0.2	0.2	0.1	0.2	0.1	0.1	0	2.3
Springfield	0	0	0.7	0.8	0.3	0.3	0.1	0	0.1	0	0.1	0.1	2.5
Cairo	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0	1.2
Missouri.													
Kansas City	0	0.1	0.5	0.9	0.9	0.6	0.2	0.1	0.2	0.4	0.2	0.1	4.2
Columbia	0.2	0	0	1.1	0.5	0.6	0.1	0	0.3	0.5	0.2	0	3.5
Hannibal	0.2	0.2	0.3	0.8	0.7	0.4	0	0	0	0.1	0.1	0	2.8
St. Louis	0.1	0	0.4	0.6	0.6	0.2	0.4	0	0.2	0.1	0.1	0	2.7
Springfield	0	0.3	0.1	0.5	0.7	0.1	0	0.1	0	0.1	0.2	0.1	2.2
Arkansas.													
Fort Smith	0.2	0.3	0.3	0.6	0.4	0.5	0.1	0	0	0	0.1	0	2.5
Little Rock	0.1	0.4	0.1	0.4	0.3	0.4	0.1	0	0.1	0	0.1	0.1	2.1

Gulf Region.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Texas.													
Amarillo	0	0.2	0.1	0.5	0.8	0.5	0.2	0.2	0	0.2	0.2	0	2.9
Abilene	0	0.2	0.6	0.6	1.5	0.2	0.2	0.1	0	0.1	0.1	0.1	3.7
El Paso	0	0.1	0.1	0.3	0.3	0.3	0.1	0	0.3	0.1	0.2	0.1	1.9
Del Rio	0	0	0.1	0.1	0.3	0	0.1	0	0	0	0.1	0	0.7
San Antonio	0	0.3	0.1	0.5	0.5	0	0.1	0	0.1	0	0	0	1.6
Fort Worth	0.1	0.3	0.3	0.8	0.5	0.4	0.1	0	0.1	0	0.1	0.1	2.8
Palestine	0.2	0.2	0	0.3	0.6	0.1	0	0	0.1	0	0.1	0.1	1.7
Corpus Christi	0	0	0.1	0.3	0.4	0	0	0	0	0.1	0	0.1	1.0
Galveston	0	0.1	0.3	0.2	0	0	0	0	0	0.1	0.2	0	0.9
Louisiana.													
Shreveport	0.1	0.5	0	0.2	0.1	0.1	0	0.1	0.1	0	0.1	0.1	1.4
New Orleans	0.2	0.2	0.2	0.5	0.3	0.1	0.1	0.1	0.1	0	0.1	0	1.9
Mississippi.													
Vicksburg	0.2	0.4	0.2	0.5	0.2	0.2	0	0.1	0.3	0	0.1	0.1	2.3
Meridian	0	0.1	0	0.7	0.1	0	0	0.1	0	0	0	0	1.0
Alabama.													
Birmingham	0.1	0.4	0.1	0.4	0.4	0.2	0.4	0.1	0.1	0.1	0	0	2.3
Montgomery	0.1	0.2	0.2	0.4	0.1	0.3	0.1	0	0	0	0	0	1.4
Mobile	0.1	0	0.1	0.6	0.4	0	0.1	0	0	0	0.1	0	1.4
Florida.													
Pensacola	0	0.2	0.3	0.4	0.3	0	0	0	0	0	0	0.2	1.4
Jacksonville	0	0	0.1	0.2	0.4	0.6	0	0	0.1	0	0	0	1.4
Tampa	0	0	0	0	0.1	0	0	0.1	0	0	0	0	0.2
Jupiter	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0.2
Key West	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Great Lakes Region.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Wisconsin.													
Green Bay	0	0	0.2	0	0.1	0.1	0.2	0	0.1	0.1	0.1	0	0.9
La Crosse	0	0	0.2	0.6	0.9	0.5	0.3	0.2	0.2	0	0.1	0	3.0
Madison	0	0	0.1	0.6	0.5	0.3	0.3	0	0	0	0.2	0	2.0
Milwaukee	0	0.1	0	0.3	0.7	0.1	0.2	0.1	0.2	0.2	0.1	0	2.0
Michigan.													
Marquette	0	0	0.1	0	0.2	0.3	0.3	0	0.1	0	0	0	1.0
Escanaba	0	0	0	0.2	0.5	0.5	0.4	0.4	0	0	0	0	2.0
Sault Ste. Marie	0	0	0	0.1	0	0.1	0.3	0.1	0	0	0	0	0.6
Alpena	0	0	0.3	0	0.3	0.1	0.2	0.1	0.3	0	0.1	0	1.4
Grand Haven	0	0	0.2	0.2	0.6	0.1	0.1	0	0	0.3	0.1	0	1.6
Grand Rapids	0	0	0.1	0.4	0.3	0.1	0.2	0.1	0.3	0.2	0.1	0	1.8
Detroit	0	0	0	0.6	0.3	0.8	0.1	0.1	0	0.1	0.1	0	2.2
Houghton	0	0	0.1	0.1	0.2	0.3	0.1	0.2	0	0	0	0	1.0
Port Huron	0	0	0.1	0.3	0.3	0.2	0.1	0.1	0.1	0	0	0	1.2

TABLE 1.—*Average number of days with hail, 1906-1915*—Continued.

Ohio Valley.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Indiana.													
Indianapolis	0.1	0.1	0.2	0.2	0.5	0.3	0.4	0	0.2	0.1	0	0	2.1
Evansville	0.1	0.3	0.3	0.5	0.7	0	0.2	0.1	0.1	0.1	0.2	0	2.6
Ohio.													
Toledo	0	0	0.2	0.4	0.2	0.3	0.3	0.1	0	0.1	0.1	0	1.7
Sandusky	0	0	0.3	0.4	0.2	0.2	0.3	0.1	0	0.1	0	0	1.6
Cleveland	0.1	0	0.1	0.5	0.2	0.3	0.2	0	0.2	0.2	0	0	1.8
Columbus	0	0	0.3	0.3	0.3	0.1	0.3	0.1	0.1	0	0.1	0	1.6
Cincinnati	0	0	0.1	0.4	0.3	0.3	0.2	0	0	0.1	0	0	1.4
West Virginia.													
Parkersburg	0.1	0.2	0	0.5	0.6	0.7	0	0	0	0.2	0	0.1	2.4
Elkins	0	0.1	0.2	0.6	0.6	0.4	0	0.1	0.1	0	0.1	0.1	2.3
Kentucky.													
Louisville	0.1	0	0.3	0.3	0.2	0.2	0.5	0	0.2	0	0.3	0.1	2.2
Lexington	0	0.1	0.3	0.4	0.1	0.4	0.1	0.1	0.1	0.1	0	0	1.7
Tennessee.													
Nashville	0	0.1	0.4	0.2	0.5	0.4	0.2	0	0	0	0	0.1	1.9
Knoxville	0.1	0.2	0.2	0.5	0.1	0.2	0.3	0.2	0.1	0	0.1	0	2.0
Chattanooga	0	0.2	0.3	0.7	0.3	0.2	0.1	0.1	0	0	0	0.1	2.0
Memphis	0.1	0.6	0.2	0.4	0.2	0.3	0	0	0	0.2	0	0.2	2.2

New England.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Maine.													
Eastport	0.2	0	0.1	0.1	0	0	0.1	0	0	0.1	0	0.1	0.7
Portland	0	0	0.1	0.1	0.2	0	0.1	0.1	0.1	0	0	0	0.7
New Hampshire.													
Concord	0.1	0	0.1	0.1	0.3	0.1	0.3	0.1	0	0.2	0.1	0	1.4
Vermont.													
Northfield	0	0	0.1	0	0.1	0.4	0.2	0	0	0.1	0	0	0.9
Massachusetts.													
Boston	0	0	0	0	0	0	0.1	0	0.1	0	0.1	0	0.3
Nantucket	0	0	0.2	0	0.1	0	0	0	0.1	0.1	0.2	0.1	0.8
Rhode Island.													
Providence	0	0	0.1	0	0.3	0.1	0	0.1	0	0	0	0	0.6
Block Island	0	0	0.3	0.1	0	0	0	0	0	0	0.2	0	0.6
Connecticut.													
Hartford	0	0	0.1	0	0.3	0.2	0.3	0.1	0	0	0.2	0	1.2
New Haven	0	0.1	0.1	0	0.2	0	0.1	0.1	0.1	0	0.1	0	0.8

Middle Atlantic States.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
New York.													
Albany	0.1	0	0.2	0	0.5	0.2	0.3	0.2	0.1	0	0.1	0	1.7
Syracuse	0	0.1	0	0.1	0.3	0.3	0.3	0.1	0	0.1	0	0	1.3
Oswego	0	0	0.1	0.1	0.1	0.3	0.1	0.1	0.2	0.6	0.6	0	2.2
Rochester	0	0	0.1	0	0.1	0.1	0.1	0	0.3	0.2	0	0	0.9
Buffalo	0	0	0.1	0.1	0.3	0.2	0.1	0.1	0	0.1	0.2	0	1.2
Binghamton	0.1	0	0	0.1	0.1	0.4	0.2	0.1	0.1	0.2	0.1	0	1.4
New York City	0.1	0.1	0.1	0	0.2	0.2	0.2	0.1	0	0	0	0	1.0
New Jersey.													
Atlantic City	0	0	0.2	0.1	0.1	0.2	0	0.1	0	0	0	0	0.7
Pennsylvania.													
Erie	0.1	0	0.2	0.3	0	0.4	0.1	0.1	0.3	0.4	0.3	0.1	2.3
Pittsburgh	0.1	0	0.3	0.6	0.3	0.3	0	0.3	0	0	0	0.1	2.0
Harrisburg	0	0.1	0	0.6	0.3	0.2	0.2	0.1	0.1	0.2	0	0	1.8
Scranton	0.1	0	0	0.3	0.3	0.8	0.4	0.1	0	0.1	0	0.1	2.2
Philadelphia	0	0.1	0.1	0	0.1	0.2	0.1	0.3	0	0	0.1	0	1.0
Maryland.													
Baltimore	0.3	0	0.1	0	0	0.4	0	0	0	0	0	0	0.8
District of Columbia.													
Washington	0	0.1	0.2	0	0.1	0.3	0.4	0.1	0.1	0	0.1	0	1.4
Virginia.													
Richmond	0.1	0	0.1	0.5	0.3	0.2	0.1	0.1	0	0.1	0	0.1	1.6
Wytheville	0	0.1	0.2	0.1	0.4	0	0.2	0.1	0.1	0	0	0	1.2
Lynchburg	0.1	0	0	0.1	0	0	0.1	0	0	0	0	0	0.2
Norfolk	0	0.1	0.3	0.2	0.3	0.3	0.1	0	0	0	0	0	1.3

TABLE 1.—*Average number of days with hail, 1906-1915*—Continued.

South Atlantic States.

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
North Carolina.													
Raleigh	0	0.2	0.1	0.1	0.2	0	0	0.1	0	0	0.1	0.1	0.9
Asheville	0	0.1	0.1	0	0.2	0.2	0.3	0.2	0	0	0	0	1.1
Charlotte	0.2	0.1	0.5	0	0	0	0.3	0	0	0	0.1	0.5	1.7
Wilmington	0	0	0.3	0.1	0	0.2	0	0	0	0	0	0	0.6
South Carolina.													
Columbia	0.1	0	0.2	0	0.2	0.3	0.1	0.2	0	0	0	0.1	1.2
Charleston	0	0.1	0	0.1	0.1	0	0	0.1	0.1	0	0	0	0.5
Georgia.													
Atlanta	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0	0.3	0.1	0.3	1.9
Augusta	0	0	0	0	0	0	0.1	0	0	0	0	0	0.1
Macon	0	0	0.2	0.1	0.3	0	0.3	0	0.1	0	0	0	1.0
Savannah	0	0	0	0	0.5	0.1	0	0	0	0	0	0	0.6

LIGHTNING AND FOREST FIRES IN CALIFORNIA.

By ANDREW H. PALMER, Observer.

[Dated: U. S. Weather Bureau office, San Francisco, Cal., July 14, 1916.]

The inauguration of the fire-weather warning service as a part of the work of the U. S. Weather Bureau has opened another interesting field for investigation in meteorology.[1] New problems have presented themselves for solution. The difficulties encountered to date have been largely the result of a lack of data, the absence of normals, and the want of precedent. Though forest fires doubtless occurred long before man appeared on the earth, a systematic record as to their causes extends over comparatively few years. In the United States the matter was not given serious attention until 1880, when a table of forest-fire statistics was prepared as a part of the Tenth Census. The investigation of the relation of weather to forest fires is of even more recent date, while the fire-weather warning service was inaugurated in the Pacific Coast States in 1913 on the recommendation of District Forecaster E. A. Beals.

With reference to their origin, forest fires may be divided into two groups, those caused by man and those caused by nature. While those caused by man are the larger of the two groups, it is not the purpose of this paper to discuss them in detail. Those caused by nature may be subdivided into three groups, (1) those caused by "spontaneous" combustion, (2) those caused by volcanic eruptions, and (3) those caused by lightning.

"Spontaneous" combustion is a direct cause of forest fires only in rare instances, and as an observed source there are few cases on record. However, of the many forest fires of unknown origin it is believed that some, at least, were thus produced. The exudation of oils and other mineral matter from the ground, or the close packing of damp leaves and grass on the forest floor may at times produce chemical reactions which might result in combustion. Forest fires caused by volcanic eruptions had not been recognized in the United States until May 19, 1915, when an eruption of Lassen Peak in northeastern California was accompanied by a blast of superheated gases which kindled two forest fires in that vicinity.[2] As natural causes of forest fires spontaneous combustion and volcanic eruptions must therefore be considered rare in the United States. The third natural cause, lightning, and its relation to forest fires, is the subject of this discussion.

LIGHTNING AND FOREST FIRES IN THE UNITED STATES.

On the national forests of the United States during the five-year period 1911-1915, inclusive, fires were caused as follows: Railroads, 14.4 per cent; campers, 15.6 per cent; brush burning, 7.9 per cent; lumbering, 1.8 per cent; lightning, 29.5 per cent; incendiary, 8.7 per cent; miscellaneous, 5.2 per cent; and unknown, 16.8 per cent. Lightning is a more important factor in causing forest fires than it is in causing fires in cities, the proportion being in the ratio of 7 to 1.

The relation of lightning to forest fires in the United States was studied in 1912 by Mr. Fred G. Plummer, of the United States Forest Service.[3] The more important conclusions reached by Mr. Plummer may be briefly summarized as follows:

Trees are the objects most often struck by lightning, because: (*a*) They are the most numerous of all objects; (*b*) as a part of the ground, they extend upward and shorten the distance to a cloud; (*c*) their spreading branches in the air and spreading roots in the ground present the ideal form for conducting an electrical discharge to the earth. Any kind of tree is likely to be struck by lightning. The greatest number struck in any locality will be the dominant species. The likelihood of a tree being struck by lightning is increased: (*a*) If it is taller than surrounding trees; (*b*) if it is isolated; (*c*) if it is on high ground; (*d*) if it is well (deeply) rooted; (*e*) if it is the best conductor at the moment of the flash; that is, if temporary conditions, such as being wet by rain, transform it for the time from a poor conductor to a good one. Lightning may bring about a forest fire by igniting the tree itself or the humus at its base. Many forest fires caused by lightning probably start in the humus. Other things being equal, trees growing in different soils differ slightly in susceptibility to lightning stroke. One study gave these results: Loam, 23 per cent; sand, 18 per cent; clay, 17 per cent; and others, 42 per cent. Zones of marked hazard from lightning—due partly to soil variations, partly to mineral deposits, and partly to altitude—are recognized throughout the West. The conductivity of wood is governed by its moisture content and its temperature. Electricity traverses wood more easily in the longitudinal direction of its fibers than across them. About 2 per cent of trees struck by lightning are ignited. While trees do not differ greatly as to their susceptibility to lightning, they do differ greatly as to inflammability.

LIGHTNING AND FOREST FIRES IN CALIFORNIA.

In California there are 18 national forests in which are included a total area of 19,575,000 acres. Not all of this land is timbered, but there are about 17,400,000 acres of standing timber in the State. These 18 national forests, which are separate and distinct from the national parks, are shown in outline in figure 1. As California is a large State containing 5 per cent of the total area of the country, and as it has within its borders a great variety of topography, soil, and climate, its trees include 125 of the 500 to 600 species growing in the United States. An

[1] Concerning the fire-weather warning service see this REVIEW, March, 1916, 44: 133-139.—EDITOR.

[2] *Palmer, A. H.* An eruption of Lassen Peak. MONTHLY WEATHER REVIEW, October, 1916, 44: 571-572.

[3] *Plummer, Fred G.* Lightning in relation to forest fires. Washington, 1912. (Forest Service Bulletin 111.)

excellent opportunity is therefore offered for investigating the relation of weather and climate to forests, and the following remarks refer only to conditions which obtain in California.

The forests of California are confined mainly to the foothills and mountains. The level interior valleys and the barren deserts of the south are practically free from extensive forest growth. While soil is an important factor in determining forest distribution, climatic conditions are of even greater importance. Of these temperature and rainfall predominate. The desert regions of the south and the broad, fertile valleys of the San Joaquin and the Sacramento are too dry in the summer to allow vigorous forest development. By far the most important climatic control is precipitation, which varies from practically nothing to more than 100 inches per year in different parts of the State. On the average, precipitation increases with height above sealevel up to a certain level, above which it diminishes again. Up to the 6,500-foot level there is an average increase of about 0.9 inch in the annual rainfall with every 100-foot increase of height above sealevel, the rate of increase being particularly marked between the 3,000- and 4,000-foot levels. Beyond the 6,500-foot level the rate of increase becomes negative; that is, the mean annual precipitation decreases with height. The Sierra Nevada, while not perpetually snow covered, receives, during the winter months, the heaviest known snowfall in the United States. The State also has a distinct wet and a dry season, though the distinction is less marked in the mountains than elsewhere.

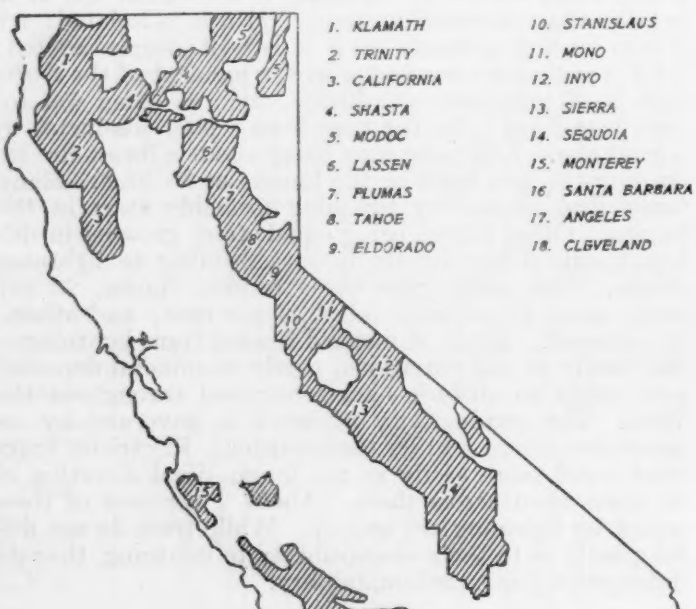

FIG. 1.—Outline map of California showing the locations and extents of its national forests.

Partly because of the increased precipitation and a more nearly uniform distribution throughout the year, and partly because of the absence of excessive heat during the summer months, the forest regions coincide with the elevated portions of the State. Distance from the coast is also a factor which determines the distribution of certain trees. For example, the coast redwood, *Sequoia sempervirens*, one of the most typical of California trees, is found only within 30 miles of the coast. This is because it requires considerable moisture and a damp atmosphere throughout the year, and it can not endure severe temperature extremes. It is one of the few trees that can extract measurable precipitation from the fogs so common along the California coast in summer. A forest of this kind is dripping wet during a fog, the foliage acting as a condenser.

Weather when considered in its relation to the various causes of forest fires may be either a direct or an indirect influence. As an indirect factor it is more important than as a direct cause. This arises from a complex combination of conditions, which may be summarized briefly as follows: A drought is a prerequisite of a forest fire. High winds, partly because they accelerate evaporation, but principally because of their fanning effect are second only in importance to droughts as a contributory factor. Hot, northerly, desiccating winds, characteristic of the front portion of an anticyclone, are the most troublesome predisposing cause of forest fires in California. Moreover, the fine dry weather brings out the campers, increases the amount of railroad traffic, as well as the lumbering and brush burning, and thus further contributes to the fire hazard. As an indirect influence, therefore, the importance of the weather in its relation to forest fires is paramount.

It is as a direct cause of forest fires, however, that weather is here considered. Lightning is the sole direct agent through which weather operates to produce fires of this kind. Table 1 shows the fires, classified by causes, on the national forests of California for the eight-year period, 1908–1915, inclusive. Of the 7,789 fires observed during that period, 2,434, or at least 31 per cent, were due to lightning. Of the 6,353 fires in which the causes were determined, at least 38 per cent were due to lightning, but it is recognized that yet larger numbers might be nearer the truth since records are known to be incomplete for the present purpose. It was the most important single cause of forest fires. Both for the United States as a whole, with 29.5 per cent, and for California with 31 per cent lightning leads while railroads were fourth and fifth in importance, respectively. The difference is due partly to the relatively greater number of thunderstorms in the California forests, and partly to the relatively smaller amount of railroad traffic.

Of those forest fires whose causes were determined the percentage due to lightning each year was as follows: 1908, 37; 1909, 26; 1910, 32; 1911, 47; 1912, 33; 1913, 55; 1914, 36, and 1915, 25. The actual number of fires, as well as the number resulting from lightning, varied greatly from year to year, as is indicated in the table. However, lightning was the leading single cause in six of the eight years, careless campers in 1909 and 1915 alone causing more fires than lightning. If but 2 per cent of trees struck by lightning in California ignite, as Mr. Plummer states is true for the United States as a whole, it means that 121,700 trees were struck by lightning on the national forests of California during the eight years, or an average of 15,212 trees each year.[4] The importance

[4] The U. S. Forest Service states that even with the perfected fire-detection system some trees are doubtless struck by lightning which are never detected by the lookout men. Further it is the general practice not to include in fire reports fires due to lightning which do not require the presence of rangers or patrolmen. Rains often immediately follow lightning storms, thus making it unnecessary for the protective force to look after all fires caused by lightning.

From these considerations it appears that the reported cases furnish minimum figures rather than precise averages.—EDITOR.

FIG. 2.—An earlier stage in the development of a very severe thunderstorm either over or behind Mount Shasta, Cal. (Photo by C. A. Gilchrist.)

FIG. 3.—Mid-winter view of a forest near the summit of the Sierra in the region of greatest known snowfall in the United States. (Photo by A. H. Caine.)

FIG. 4.—In the heart of a mountain forest in January in the Sierra. This snow protects against winter fires and will become available as ground moisture during the long summer drought. (Photo by A. H. Caine.)

of lightning as a factor in the causes of forest fires is apparent from these figures.

TABLE 1.—*Fires in national forests in California, classified by causes.*

[Statistics furnished by U. S. Forest Service.]

Causes.	*1908	*1909	*1910	1911	1912	1913	1914	1915	Total.		Average number per year.
									No.	*P. ct.*	*No.*
Railroads	12	22	11	24	93	64	70	25	321	4	40
Campers	108	99	63	71	98	214	340	395	1,388	18	174
Brush burning	17	37	29	38	42	78	45	75	361	5	45
Lumbering	......	14	11	15	29	46	69	71	255	3	32
Lightning	158	84	110	282	206	804	480	310	2,434	31	304
Incendiary	13	17	59	92	71	133	212	301	898	12	112
Miscellaneous	117	51	66	80	83	111	111	77	696	9	87
Unknown	103	152	204	195	190	178	141	273	1,436	18	180
Total	*528	*476	*553	797	812	1,628	1,468	1,527	7,789	100	974

* Returns less complete for these years.

It is probable that few forest fires pass unobserved. During 1915 the U. S. Forest Service in California employed 85 lookout men and 555 rangers, patrolmen, and firemen. The lookout men were stationed on high peaks and reported fires to the district ranger by telephone or heliograph. In addition, private owners employed 80 patrolmen.

Lightning rarely occurs independently of a thunderstorm. Thunderstorms, however, are of various kinds. Those along the coast are limited almost entirely to the winter half-year, and are invariably of cyclonic origin, caused by the overrunning of a relatively warm stratum of air by one relatively colder. They come in ready-made from the ocean, are of short duration, and of feeble intensity, with few electric discharges in the form of lightning. But one thunderstorm occurs each year on the average at San Francisco. In the mountain regions, however, where most of the forests are situated, thunderstorms occur throughout the year, though they are most frequent during the summer months. They are often violent and long continued, and are accompanied by numerous lightning discharges. Under the strong insolation which California receives during the long summer days, local heating of the air results in vertical convection which produces cumulus clouds, a characteristic feature of the landscape during afternoon hours. Under favorable conditions, which include moderate or high humidity and calms or light winds, these cumulus clouds become overdeveloped and produce cumulo-nimbus, or thunderheads. The photograph shown in figure 2 was taken by Mr. C. A. Gilchrist and is here reproduced through his courtesy. It shows a stage in the formation of a thunderstorm over Mount Shasta. This particular storm subsequently attained great violence, and was accompanied by destructive lightning. As indicated in the foreground, the view was taken during the haying time of early summer, when snow was still abundant on Shasta. The summit of this mountain is 14,380 feet above sealevel and more than 2 miles above the floor of the valley shown in the foreground. It would thus appear that the cirrus cap at the top of the ascending column must have been fully 5 miles above the top of the mountain, or about 8 miles above sealevel.

During the summer months the weather of California is dominated by the great North Pacific HIGH. For this reason the surface winds are local in origin, while the upper air is almost stagnant, as far as horizontal currents are concerned. The amount of rain which accompanies these local thunderstorms varies greatly, though it is generally light. No relation is apparent between the amount of rain which falls during one of these storms and the number of lightning flashes. However, it has been observed that the deeper the storm; that is, the greater the height reached by the ascending current, the more frequent are the electrical discharges. When lightning strikes a forest tree the accompanying rainfall will often prevent ignition, thus accounting in part, at least, for the fact that 98 per cent of trees struck by lightning are not set on fire. Moreover, a rainfall of 0.25 inch will make it practically impossible for a fire to spread. Many thunderstorms, however, are accompanied by no measurable rainfall. Furthermore, when anticyclonic conditions are well developed the resulting surface winds are from the north or northeast, the direction of most dangerous "fire winds" in the State. Partly because of their excessive dryness, but principally because of their fanning effect, these winds are most dreaded by foresters while fighting a forest fire.

It might be inferred from the foregoing that lightning as a factor in causing forest fires, varies with different forests as well as with different years. That such is the case may be noted from Table 2, which shows the number of fires on the 18 national forests during the four years, 1912–1915, inclusive, and the number and percentage caused by lightning. It is noteworthy that the Santa Barbara Forest, the one nearest the coast, had the least number of lightning fires, and not a single fire caused by lightning in 1912 or in 1915, though 50 fires occurred during the former year and 147 fires during the latter year. On the other hand the Modoc Forest, the one farthest distant from the coast and well up in the mountains, had relatively the greatest number of lightning fires, 84.6 per cent of those in 1912 and 72.2 per cent of those in 1915 having been so caused. The great contrast is due principally to the difference in the frequency and in the nature of thunderstorms in the two forests, the one at a low altitude along the coast, the other at a great altitude in the interior.

Thunderstorms, like certain other elements of the weather, vary in number from year to year, and for this reason the number of lightning fires varies. As may be inferred from figures 3 and 4, which are winter photographs of California forests taken by Mr. A. H. Caine, thunderstorms which occur during that season rarely start forest fires. The humus and forest litter is then either snow covered or has been saturated by rains. In these mountain regions 85 per cent of all the precipitation received during the course of the year falls in the form of snow. Moreover, the violent thunderstorms originating from local surface heating are then infrequent. The great majority of forest fires in California occur during the months, July to September, inclusive. The winter snow is important in another respect. It is recognized that susceptibility to forest fires during the summer months depends not only upon the character of that season, but also upon the amount of snow which fell the preceding winter and the manner and rate of its disappearance upon melting. The importance of these considerations is apparent when the dryness of the forest floor is recognized as a factor. The average man, unacquainted with forest conditions, would marvel at the ease with which such an apparently green forest would ignite, even though the snow has but recently melted. Figure 5 is another photograph of Mount Shasta, showing a forest and lumber piles at its base. Sparks blowing from the smokestacks of sawmills like the one here shown were formerly a prolific source of forest and lumber-yard fires. The adoption of efficient spark screens has now largely eliminated that cause of fires.

TABLE 2.—*Fires in the national forests in California showing number and percentage caused by lightning during 1912–1915.*

[Statistics by U. S. Forest Service.]

Forest. [Cf. Fig. 1.]	1912			1913			1914			1915		
	Total number of fires.	Lightning fires.		Total number of fires.	Lightning fires.		Total number of fires.	Lightning fires.		Total number of fires.	Lightning fires.	
	No.	*No.*	*P. ct.*	*No.*	*No.*	*P. ct.*	*No.*	*No.*	*P. ct.*	*No.*	*No.*	*P. ct.*
Angeles	72	2	3	130	27	21	136	4	3	116	7	6
California	20	5	25	76	35	46	48	6	12	24	1	4
Cleveland	41	0	0	72	43	60	78	14	18	37	1	3
Eldorado	22	2	9	74	10	14	46	15	33	74	5	7
Inyo	3	1	33	5	3	60	4	3	75	3	0	0
Klamath	85	32	38	126	85	67	163	103	64	219	37	17
Lassen	65	40	62	77	48	62	95	60	63	92	34	37
Modoc	26	22	85	49	36	73	51	35	69	72	52	72
Mono	4	2	50	6	6	100	5	1	20	15	5	33
Monterey	5	0	0	8	0	0	2	0	0	15	2	13
Plumas	96	30	31	156	84	54	149	32	22	108	27	25
Santa Barbara	50	0	0	63	5	8	57	3	5	147	0	0
Sequoia	80	3	4	127	91	72	81	47	58	36	10	28
Shasta	56	29	52	129	62	48	133	34	26	196	77	39
Sierra	67	1	1	172	77	45	88	30	34	37	4	11
Stanislaus	23	3	13	101	49	48	58	12	21	30	4	13
Tahoe	60	5	8	120	45	38	223	53	24	163	17	10
Trinity	37	29	78	137	98	72	53	28	53	143	27	19
Total	**812**	**206**	**25**	**1,628**	**804**	**49**	**1,468**	**480**	**33**	**1,527**	**310**	**20**

Total number of fires during 4-year period	5,435
Number of lightning fires during same period	1,800
Average annual number of lightning fires	450
Percentage of lightning fires to total number	33

It should be borne in mind that all forest fires started as small fires. When lightning strikes a tree it may ignite the tree or the débris and undergrowth beneath, the fire later spreading if conditions are favorable. Of the three kinds of fires recognized by the Forest Service, all may be caused by lightning. These three kinds are (1) ground fires, which smolder indefinitely in the ground, consuming humus, duff, and roots of trees; (2) surface fires, which spread over the surface of the forest floor, fed by undergrowth and débris; and (3) crown fires, which consume the entire forest cover.

As in other States, California has zones peculiarly susceptible to lightning; zones which are perhaps independent of possible topographic influences. Every ranger and lookout recognizes certain well-defined belts where lightning strikes most frequently. As a result, many local traditions have arisen and most of these are based on accurate observations.

According to Mr. Plummer[5] scars traceable in the annual rings of the famous Big Trees of California suggest that great forest fires occurred about the years 245, 1441, 1580, and 1797 A. D. It is known that the American Indians have occasionally set fire to forests in order to clear the land for agriculture, to drive game, or to impede the progress of an enemy, but it is more likely that these great fires were kindled by lightning. These trees also refute the popular superstition that lightning never strikes twice in the same place. Certain trees are known to have been struck eight times, with no other apparent effect than a dwarfed growth.

CONCLUSION.

The importance of lightning as a cause of forest fires may be judged from the foregoing statements. Being of natural origin, lightning is one of the factors which can never be eliminated. However, the situation is not hopeless. The main hope lies in the anticipation of fires and the making available of facilities to subdue them when they occur. The fire-weather warning service gives hope of reward. Thunderstorms with their destructive lightning form simply one of the elements which must be considered. In this, as in other branches, the dominant need is for more field work in order to secure more complete data with reference to each individual forest. As this information is secured further advance may be expected of meteorology in general, and of fire-weather forecasting in particular.

[5] *Plummer, Fred G.* Forest fires. Washington, 1912. (Forest Service Bulletin 117.)

THE DENSITY OF SNOW.

By Prof. ALFRED J. HENRY.

WITH A NOTE ON THE DISAPPEARANCE AND SETTLING OF SNOW IN 1915-16 NEAR RENO, NEV.

By HENRY F. ALCIATORE, Meteorologist.

CONTENTS.

Definitions.—The generic term density is defined as *mass divided by volume*, or mass per unit volume. The literature of the density of snow frequently contains such terms as "relative" density, "specific" density, and "specific gravity," all of which are comprehended in the simple term density. Relative density as ordinarily defined is the ratio of the mass of any volume of the substance to an equal volume of a standard substance. Water at a specified temperature and pressure is generally taken as the standard substance for solids and liquids and hydrogen for gases. The "specific" density of a substance is merely another way of expressing the specific gravity of the substance. The terms "specific density" and "specific gravity" are interchangeable.

In this paper the term "density" is considered as equivalent to either "relative" density, "specific" density, or "specific gravity" of snow, and it will be expressed numerically as a three-place decimal. Thus, 0.100 (read one hundred thousandths,) that is, snow having a density of 1 to 10, or water equivalent of 1 inch in 10. By disposing of the third decimal, the density values may be thought of as percentages.

The rule followed by the Weather Bureau in disposing of decimals is to increase the last significant figure by

FIG. 5.—Another view of Mount Shasta showing forests about its base, with a sawmill and lumber piles in the foreground. These forests are particularly susceptible to fires from lightning.

unity when the decimal is greater than 5 and to disregard all decimals less than 5. When the decimal to be dropped is 5 exactly, the preceding figure, when odd, will be increased by 1, and when even will remain unchanged.

THE LITERATURE OF SNOW DENSITY.

The greater part of the literature on the subject is in foreign publications; a selected bibilography of papers consulted is presented at the end of this paper.

The subject "snow density", in a broad sense, has developed unevenly, and indeed I may say that it is yet in a state of development. The part taken by the Signal Service and its successor, the Weather Bureau, is outlined in the next paragraph. From this it will be seen that the great, and practically the only, desideratum in the beginning was to determine the quantity of water precipitated as snow. The density of the snow did not seem to be important.

The credit of having pointed out the relation of a snow cover to subsequent weather is due to the late Russian meteorologist, Voeĭkov (Woeikof), more than to any other single person. He first drew attention to the subject in 1871, and his second communication was followed nearly 20 years later by another much greater work, "The Influence of a Snow Cover on Soil, Climate, and Weather" (No. **5** in the list of references at the end of this paper). Preceding the date of publication of the last-named work, the meteorologists of India were engaged in a correlation of the snowfall of the Himalaya, with the subsequent rainfall of the upper Provinces of India.

THE MEASUREMENT OF SNOW IN THE UNITED STATES.

Historical.

Smithsonian Institution.—Systematic meteorological observations in the United States, including the measurement of precipitation in the form of snow, under the direction of the Smithsonian Institution, began about 1848.[1] Smithsonian observers were instructed to use a snowgage and to melt the catch of snow and record the amount of melted snow as rain. Explicit directions were given to guard against evaporation in the process of melting. Rain water and melted snow water were to be entered in separate columns in the record. The water equivalent of snow was recognized as being on the average 1/10, but the alternative of recording 1/10 of the average depth instead of melting was not authorized.[2]

The Signal Service and the Weather Bureau.—The earliest definite instructions upon the subject issued by the United States Signal Service are given in Instructions to Observer-Sergeants, dated September 30, 1873. These instructions provide that "Snow will be melted and then measured in the same manner as rainfall," evidently following the practice of the Smithsonian Institution, the then recognized authority on meteorological matters in the United States. A revision of the 1873 instructions as to snow measurements, made in 1875, repeated the original instructions with an added clause as follows:

> Whenever from any cause snow can not be melted, the depth will be measured and 10 inches of snow recorded as 1 inch of rainfall.

This is the first occasion of the public recognition of the ratio 1/10 by authorities in the United States.

In the 1881 edition of Instructions to Observers, the above specifications were repeated. In April, 1884, however, a very material amendment was promulgated as General Orders No. 40, April 11, 1884. This order directs the use of a snowgage and describes it (the gage described is practically the overflow of the present 8-inch standard raingage) and specifically directs the following be made of record:

(1) Time of beginning and ending of snow.
(2) Whether moist or dry.
(3) Amount of water collected in the snowgage from snow (or snow with rain).
(4) The same collected in the raingage.
(5) Depth of snow (before melting it) collected in the snow gage at each telegraphic observation.

The revision of 1887 includes the foregoing items but is silent as to the date upon which they became effective. Reference to the original order shows that it became effective July 1, 1884. No change was made in the next revision, which appeared in 1895 under the title "Instructions for Observers of the Weather Bureau", Washington, 1895. A short time previous to the last-named date, probably in 1894, Prof. C. F. Marvin, then in charge of the Instrument Division, published as Circular A, of that division, a pamphlet under the title "Instructions for Obtaining and Transcribing Records from Recording Instruments". In this publication, it was recognized that the ratio 1/10 was only roughly approximate and the observers were urged to determine the actual water equivalent of snow by either of two suggested methods. These instructions were later amplified somewhat and now appear in Circular E, Instrument Division, "Measurement of Precipitation"[3] and also in the pamphlet entitled "Instructions for Preparing Meteorological Forms", the latter first issued in 1905 and revised annually since that year. The 1916 edition contains directions for measuring snow under paragraph No. 110. The ratio 1/10 is still used when the observer is unable to melt the snow.

The water equivalent of fresh snow.

In the beginning of systematic snow measurements, observers were chiefly concerned with (1) the best means of catching the falling snow, and (2) its water equivalent, the latter in order that the record of precipitation might be complete. It was generally recognized that there were serious difficulties to be overcome in order to secure a true catch, and also that the snow varied considerably in density. The earliest discussions of the subject are largely concerned with questions of variations in density under different temperature conditions which attend the fall of snow (see for example, **1** in list of references).

A résumé of the official instructions as to the measurement of snow in England and other countries at that time (1872) will be found in Symons's "British Rainfall for 1872", pages 9–23. The rule in England as prescribed for observers of the British rainfall organization was either of the following: (1) Melt the snow caught in the gage by the addition of a previously ascertained quantity of warm water, then deduct this quantity and measure the residue as rain; (2) select a place where the snow has not drifted, invert the funnel (of the raingage) and, turning it around, lift and melt what is inclosed; (3) measure with a rule the average depth of snow, and

[1] Earlier but less extensive corps of observers were organized in 1817 by Josiah Meigs, Commissioner General Land Office, and in 1819 by the Surgeon General of the Army. *See* MONTHLY WEATHER REVIEW, February, 1909, 37: 87–89.—C. A., jr.
[2] Smithsonian miscellaneous collections, No. 19, p. 23.

[3] Third edition, 1911 (W. B. No. 445).

take 1/12 as the equivalent of water. Observers were enjoined to try all these methods and to adopt that which they consider most trustworthy.

In subsequent issues of British Rainfall many interesting notes on the water equivalent of snow appear and it is pointed out that the ratio varies from 1/5 to 1/35.

Col. M. F. Ward, a member of the British Rainfall Organization, not only made many careful observations, but also contributed the results of his studies for publication in the annual volumes of British Rainfall. While Col. Ward's work was largely concerned with a determination of the catch of snow, yet it contains many valuable observations on snow density. A density as low as 0.026 was observed [4] by him in Canton Vaud, Switzerland, on January 16, 1880, and the remarkably low density of 0.008 was observed [5] in March, 1876. The maximum density observed was 0.221 and the mean density for different kinds of snow was [6]—

Minute crystals	0.075
Small snow	.100
Large dense flakes	.100
Large light flakes	.059
Round globules	.058

Lancaster (3) in 1888 published a summary of the existing data on snow density, based chiefly on a 20-year period of observations at the Alpine station of Grand Saint Bernard, altitude 2,478 meters, as follows:

	Mean density.
January	0.080
February	.080
March	.090
April	.110
May	.160
June	.180
July	.240
August	.180
September	.150
October	.150
November	.100
December	.080

Temperature–density relations.

Belgium.—Lancaster (3) points out that the greatest densities are observed in the summer months and the least in winter, and attempts to deduce a relation between the density of the snow and the air temperature at the time of its fall. He deduces from three years of observations, the following temperature-density relations:

Temperatures °F.:	Density.
At 36	0.166
At 34	.143
At 32	.125
From 30 to 28	.111
At 27	.100
At 25	.090
From 23 to 19	.083
From 18 to 14	.077
From 12 to 5	.071

Germany.—Wengler (21) presents an abundance of good material respecting the density of freshly fallen snow in north Germany. Using the Potsdam observations,[7] he obtains the following temperature-density relations:

Temperatures °F:	Density.
From 5 to 14	0.046
From 14 to 23	.082
From 23 to 27	.086
From 27 to 30	.089
From 30 to 32	.103
From 32 to 34	.140
From 34 to 37	.235

[4] Symons's British Rainfall, 1879, p. 16.
[5] Symons's British Rainfall, 1875, p. 24.
[6] Symons's British Rainfall, 1874, p. 29.
[7] Ergebnisse der meteorologischen Beobachtungen in Potsdam im Jahre 1910, p. VIII.

Throughout the table of densities prepared by Wengler, and especially in the last-named group (34° to 37°F.), a number of cases of relatively high density appear. These, as explained by the author, were due to several causes, frequent among which was the tendency to increased density with temperatures above 32° and the fact that it was not always possible to exclude those cases in which the precipitation was partly in the form of sleet and rain mixed.

The same author using the records of snow measurements made at Potsdam during a period of 15 years, shows the error that is probable in assuming the ratio 1/10 to subsist at all times. His results are summarized in Table 1 below.

TABLE 1.—*Observed and computed water equivalents of snow at Potsdam.*

[Ratio 1/10 used in computed amounts.]

Month.	Precipitation as snow.		Differences.	
	Measured.	Computed.		
	Inches.	*Inches.*	*Inches.*	*Per cent.*
November	4.40	3.89	−0.51	−11.6
December	3.03	3.31	+ .28	+ 9.2
January	8.31	9.06	+ .75	+ 9.0
February	5.50	5.42	+ .08	+ 1.4
March	4.85	3.82	−1.03	−21.2

The above results clearly show that for the beginning and the ending of the snow season the ratio 1/10 gives too low values and that during midwinter, as in December and January, the computed values are too high by about 9 per cent. The results for February closely approximate the truth, while in March the computed values are 21.2 per cent too low.

Wagon Wheel Gap, Colo.—An attempt to classify snow densities according to surface air temperatures as observed at the Wagon Wheel Gap Experiment Station [8] in Colorado, was not successful in establishing any definite relation between surface-air temperatures and the density of falling snow.

TABLE 2.—*Average snow densities at Wagon Wheel Gap, Colo., deduced from 6 years' observations and classified according to surface temperatures.*

Surface air temperature.	Cases.	Density.
°F.		
0 to 5	2	0.065
5 to 14	26	.097
15 to 24	57	.078
24 to 26	22	.076
27 to 30	32	.078
31 to 32	16	.085
32 to 34	11	.104
35 to 38	18	.096

Little importance is attached to this Table 2 since it is practically impossible to classify snowfall according to surface air temperature. The air temperature when snow begins to fall in the late Fall and early Winter, is of course relatively higher than in midwinter, and naturally as the fall of snow continues, the temperature falls.

Roughly speaking, snow may begin to fall at Wagon Wheel Gap at any surface temperature between 0° and 45°F. On January 4, 1913, set in a snowstorm lasting almost continuously for 30 hours. At the beginning,

[8] Maintained jointly by the Weather Bureau and the Forest Service of the Department of Agriculture.

the air temperature was 23°F. (5°C.) and falling very slowly. It reached 10°F (−12°C.) at 10 p. m. on that date; thereafter the fall was more rapid. reaching a minimum of −7°F. (−21.7°C.) at 8 a. m. the next morning. Snow continued falling until nearly 6 p. m. of the 5th. By that time, the temperature had risen from −7° to −3°F. The depth of the snowfall was 6 inches and the density 0.060. In general, the density is less in midwinter than in the transition seasons at the beginning and at the end of the cold season, respectively, as may be seen by the following table:

TABLE 3.—*Average density of fresh snow at Wagon Wheel Gap, Colo.*

Season.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
1910–11	......	......	0.089	0.076	0.075	0.075	0.077	0.118	......
1911–12	......	0.084	.070	.083	.072	.079	.076	.073	0.150
1912–13	......	.082	.074	.055	.089	.081	.080	.108	.100
1913–14	0.100	.091	.085	.073	.064	.083	.086	.072	......
1914–15	......	.145	.200	.066	.072	.076	.076	.122	.144
1915–16	.100	.090	.088	.076	.089	.097	.091	.098	......
Mean	0.100	0.098	0.081	0.071	0.077	0.082	0.081	0.098	0.131
Inches of snow to =1 inch water	10	10	12	14	13	12	12	10	7.6

The observations at Wagon Wheel Gap, Colo., it should be remembered, were made at an altitude of slightly more than 9,500 feet where the precipitation of the cold season is wholly in the form of snow.

At the majority of observing stations east of the Rocky Mountains, the precipitation, especially at the more northern points, is frequently in the form of snow turning to rain or vice versa, and there is therefore by reason of the impossibility of separating the precipitation in the two forms, a lack of conclusive data on the subject.

Washington, D. C.—At Washington, D. C., latitude 38° 54′ N., in 10 years record, there were but 29 cases of snow not mixed with rain or sleet (ice grains), about three cases on an average per season.

The average density as determined from these observations is 0.098, the least was 0.026 on March 22, 1914; the greatest was 0.175 on March 3, 1916. The depth of snow on the latter date, however, was but 0.8 inch; but the surface air temperatures were under 32°, viz, 26° at the beginning and 24° at the ending of the snow.

Special attention is given by the Weather Bureau to the collection—through its network of cooperative stations, mountain snowfall stations, and by cooperation with the rangers of the Forest Service, especially in the far western States—of statistics of depth and density of the seasons' snowfall.

A monthly bulletin is distributed near the close of each month during winter through which persons interested in the probable water supply derived from melting snow may receive the latest available information thereon.

Colorado.—Section Director Frederick H. Brandenburg (**22**) of Colorado began the issue of monthly snow bulletins for that State as early as 1896, and other section directors began soon thereafter.

We have summarized from Director Brandenburg's reports for a single season the results shown in the small table below. At each of the stations in the State, the water equivalent of the snowfall was determined, usually by melting, and a record was also made of the depth. The last column contains the average density as determined from the average depth and the water equivalent of the snow. The latter is not shown.

TABLE 4.—*Average depth and density of snow in Colorado for a single season.*

Months.	Number of stations.	Average.	
		Depth.	Density.
		Inches.	
November	29	3.0	0.064
December	29	14.0	.062
January	44	16.0	.046
February	40	22.4	.069
March	46	14.5	.075

New York.—Measurements at Albany, N. Y., north latitude 42° 39′ for two winters (29 cases) give 0.110 as the mean density.

Five observations of the density of new snow (**11**) made at the same city by Mr. R. E. Horton in the winter of 1914, give 0.165 as the mean density.

Upsala, Sweden.—Westman and Jansson (**9**) made some very definite observations on the density and diminution in depth of a snow cover at the observatory at Upsala in 1902, and the density of fresh snow was carefully determined. The studies of these observers form one of the most thorough contributions to the subject that has yet appeared. We quote from their result the following table, transposing the values into English measures, for the benefit of any of our readers in the United States who may not be thoroughly conversant with metric measures and also in order to conform to the system of measures used throughout this paper.

TABLE 5.—*Westman's & Jansson's determinations of the density and temperature of snow at Upsala.*

Date.	Hour.	The snow layer.						Precipitation during preceding 24 hours.[a]	Remarks.		
		Depth.	Temperature.				Density.		Time.	Temperature of air.	
			Surface.		Bottom.						
1902		*Inches.*	°*C.*	°*F.*	°*C.*	°*F.*		*Inches.*		°*C.*	°*F.*
Feb. 10	2:45 p. m.	3.15	......	......	......	......	0.0384±0.0023	*0.03	6-1 p. m.	−12	10.4
Feb. 10	6:25 p. m.	3.31	− 9.2	15.4	−5.4	22.3	.0476± .0025	(*)	6-6:30 p. m.	−12	10.4
Feb. 10	11:30 p. m.	3.50	− 9.2	15.4	−6.2	20.8	.0600± .0010	(*)	8:30-Midnight	−11	12.2
Feb. 11	11:25 a. m.	5.47	− 9.4	15.1	−5.2	22.6	0.0615±0.0009	(*) .19	6-11 a. m.	−12	10.4
Feb. 11	6:25 p. m.	5.12	−22.4	8.3	−7.0	19.4	.0630± .0009	......	......	......	......
Feb. 12	10:25 a. m.	4.49	− 5.0	23.0	−3.5	25.7	0.0844±0.0009	(*) .04	5:30-7:45 a. m.	− 4	24.8
Feb. 12	6:25 p. m.	4.17	−11.0	12.2	−4.6	23.7	.0921± .0009	......	......	......	......
Feb. 13	1:40 p. m.	3.70	− 8.0	17.6	−4.2	24.4	.1111± .0018	.00	......	......	......
Feb. 14	10:30 a. m.	3.54	−11.2	11.8	−7.6	18.3	0.1121±0.0016	.00	......	......	......
Feb. 15	11:20 a. m.	3.39	− 9.2	15.4	−8.4	16.9	.1210± .0009	.00	......	......	......
Feb. 16	1:00 p. m.	3.23	0.0	32.0	−1.2	29.8	.1403± .0021	.00	......	......	......

*Precipitation in form of snow.

[a] Measurements made at noon.

The authors remark on Table 5 as follows:

Variations in the specific density of a snow cover composed of recently fallen snow have been measured in only a small number of cases. Between February 10 and 12 a new layer of snow was formed while the temperature of the air was quite low and the wind velocity gentle. As this new layer was exceptionally porous and at the same time homogeneous, it was particularly favorable to a study of the variations of specific density. The snow was so soft (molle) that the cylinder above described could not be used to extract the samples, because the snow massed about the end of the cylinder without penetrating it when it was forced into the snow layer. Recourse was had to a plate of sheet iron 25 centimeters square, which was forced under the new snow at the surface of the old snow. In this manner a sample was cut in the form of a rectangular parallelopiped, having the plate as a base and the depth of the snow layer as its height. In this manner the compression of the snow was completely avoided. Having measured the dimensions and the weight of the parallelopiped, the specific density was calculated. Each of the values of specific density which appears in Table 5 is the mean of five different measurements. In that table, also, is indicated the probable error in the values of specific density and the depth and temperature of the new snow cover at the hour of observation.

It was established that there was a continual increase in the specific density, that for the most porous snow the increase was relatively rapid even though at the beginning the temperature of the air and that of the snow was not above 14° F. (−10° C.) and 15.8° F. (−9° C.). Finally, it appears that the density during the fall of snow varies between 0.0384 and 0.0844. Between the 12th and the 16th, after snow ceased falling, the increase in density continued, but was very irregular. On the average its value was 0.018 in 24 hours.

The very considerable temperature gradient in a layer of new snow is worthy of mention. It appears from Table 5 that there was on February 11 a maximum of 15.4°C for a depth of 13 centimeters, or 1.2 degrees for each centimeter, which proves that this snow was a very poor conductor of heat. For the density of the snow cover in question, 0.063, the coefficient of conduction is 0.00017°.[8] By comparison it may be noted that the value of this coefficient is for air 0.00005 and for ice 0.00568.

Density of old snow.

We now pass to a consideration of the density of a layer of snow that has been exposed to the weather for a greater or less time. Freshly fallen snow is composed of minute snow crystals intermixed with air. The quantity of air present is variable, depending on the size and structure of the crystals and, in a lesser degree, on the mechanical action of the wind. The longer snow is exposed to the weather the greater is the quantity of air which is expelled from it, and naturally the density increases. Moreover, as has been pointed out frequently by previous writers, snow that has been exposed for some time to the weather suffers a change in its internal structure, which tends to increase its density. The diminution in depth of a snow cover is generally due to several causes, acting singly or conjointly. Principal among these causes are: (1) An increase of air temperature, due to insolation or to the horizontal transport of warm air from other regions, sufficient to produce melting of the superficial layer of the snow cover; (2) the mechanical action of the wind, either in compressing the top layers or in breaking up the original snow crystals and distributing them in the form of drifts of finely pulverized snow; (3) by the evaporation and settling of the top layers, which doubtless, in the case of evaporation, must depend largely upon the climatic conditions of the region in which the snow layer may exist. The fall of rain, too, can have an important bearing on the structure of the snow cover, particularly if it is immediately followed by freezing weather. The well-known snow crust often owes its origin to this circumstance.

Intensive snow surveys in the United States.

So far as known, the first systematic measurements in the United States, of the density of the accumulated snow layer in spring were made by Mr. Charles A. Mixer (**12**), civil engineer, of Rumford Falls, Me., in the spring of 1903.

Mr. Robert E. Horton, hydraulic engineer, of Albany, N. Y., collected and published in 1905 the results of snow density measurements made in New York and New England (**10, 11**).

Within the last 10 years a number of intensive snow surveys at high altitudes, late in the spring, have been made under the direction of Weather Bureau officials, as noted in the following paragraphs. Previous work of a similar character was done by Prof. John E. Church, jr. (**24**), of the University of Nevada at Reno. In the spring of 1909 Church began a series of snow density determinations near Lake Tahoe, in the Sierra Nevada. Prof. Church has summarized the results of several thousand measurements on a series of blue-print sheets distributed in 1916. It is understood the results of his work will appear in the proceedings of the Second Pan American Scientific Congress (Washington, 1915–16), and also in a special bulletin of the Nevada Experiment Station.

Utah.—The pioneer of intensive snow surveying by the Weather Bureau is Mr. A. H. Thiessen, section director, Salt Lake City, Utah. Mr. Thiessen began with a survey of Maple Creek Canyon in the spring of 1911. The first survey covered 6,880 acres and 277 soundings for depth and density were made. The average depth was found to be 36 inches and the average density 0.320, or 32 per cent. This survey was repeated in the following year, and 297 soundings were made, or practically the same as before. These determinations gave, for the spring of 1912, an average depth of 42.5 inches and a density of but 0.240, or 24 per cent.

In 1914 the survey was made in the watershed of City Creek Canyon, from which a portion of the water supply of Salt Lake City is drawn. The results of that survey and also of the surveys in 1915 and 1916 are shown in Table 6.

TABLE 6.—*Snow densities in City Creek Canyon, Utah, 1914–1916.*

Years.	Subdivisions.								Whole area.
	A	B	C	D	E	F	G	H	
1914	0.34	0.33	0.35	......	......	0.34	0.34	0.36	0.34
1915	.32	.30	.31	0.32	0.30	.31	.32	.33	.31
1916	.36	.32	.35	.36	.33	.32	.34	.33	.34

Idaho.—Edward L. Wells, section director at Boise, made some density measurements in the neighborhood of Silver City in February, 1914. He found an average depth of 33.1 inches and a density of 0.290. In the neighborhood of Sheep Hill the depth in the same month was 27.0 inches and density 0.290.

An intensive survey was conducted under the same official in the watershed of Cottonwood Creek in 1914, 1915, and 1916. The depths and densities are given in Table 7. (See also this REVIEW, 1914, **42**: 634; 1915, **43**: 567.)

TABLE 7.—*Average depths and densities of snow in the basin of Cottonwood Creek, Idaho.*

Years.	Below 4,000 feet.		Between 4,000 and 5,000 feet.		Between 5,000 and 6,000 feet.		Above 6,000 feet.	
	Average depth.	Average density.	Average depth.	Average density.	Average depth.	Average density.	Average depth.	Average density.
	Inches.		*Inches.*		*Inches.*		*Inches.*	
1914	4.3	0.30	29.8	0.33	41.3	0.35	72.6	0.35
1915	4.0	.30	19.4	.32	26.3	.30	36.8	.30
1916	36.5	.34	46.1	.35	56.8	.37	121.0	.36

[8] *Jansson, M.* Ueber die Wärmeleitungsfähigkeit des Schnees. Ofvers., Kongl. Vet. Akad. Forh., Stockholm, 1901.

Arizona.—Depth and density measurements were made in the latter part of March, 1914, 1915, and 1916 in the Paradise Creek Valley region, Apache County, Ariz., approximately in latitude 34° N., longitude 109° 45′ W. Paradise Creek is a tributary of the White River, which latter has its source in the high mountains in the southwestern part of Apache County. The measurements of 1914 are presented in Table 8, in which the arrangement is according to altitude.

TABLE 8.—*Average snow depths and densities, Paradise Creek valley, Ari.*

Number of measurements.	Elevation.	Average depth.	Average density.
	Feet.	*Inches.*	
88	8,250 to 8,750	13.5	0.346
133	8,750 to 9,250	20.0	.319
266	9,250 to 9,750	27.6	.333
15	10,000	49.0	.305

The greatest depths were found on the north and northeast slopes. The density did not vary materially with slope. The greatest density, 0.400, was found in a layer 8 inches thick in the aspen forest. Low average densities were found in layers having a total depth of 15, 19, 30, and 50 inches, respectively. There does not appear to be an increase in density with increase in depth.

The determinations in 1914 and 1916 were made by Observer Kenneth Meaker; in 1915 by Observer B. L. Laskowski. The measurements in 1915 and 1916 were greately hindered by untoward weather conditions, it being physically impossible to prosecute the work to a successful conclusion; nevertheless, 61 determinations of depth and density were made in 1915 at altitudes ranging from 7,875 to 8,500 feet and depths were encountered ranging from 18 to 47 inches. The average depth as determined by 61 measurements was 36 inches and the average desity 0.251. Densities as great as 0.346 and as small as 0.167 were encountered. The high densities were found in a snow layer having an average depth of 32 inches. The low values were found in a layer of but 15 inches in depth.

The weather conditions in 1916 were even worse than in the preceding year and but 32 measurements were obtained. A driving wet snow had prevailed for 36 hours, and this was followed by a heavy rain, thus making roads and trails impassable. When the rain ceased the weather turned cold and on the top of the water-soaked snow formed a crust that was not strong enough to bear a horse, and hence a camp outfit could not be taken into the snow fields.

The average depth of the snow cover where measurements were practicable was 18.2 inches; its average density was 0.600. In some cases the snow layer was practically a mass of slush, having a density of 0.900. The lowest density recorded was 0.410. Flood conditions prevailed on all the streams of the region and the flood flow passed over the spillway of the Roosevelt Reservoir, the latter being full at the time.

Wyoming.—The Rock Creek Conservation Co. of Rock River, Wyo., in cooperation with the U. S. Weather Bureau, made a survey of the extent, depth, and density of the snow cover in Sand Lake, Wyo., drainage. The geographical coordinates of Sand Lake, Wyo., are approximately lat. 41° 25′ N., long. 106° 12′ W. The Medicine Bow Mountains are immediately to the westward of Sand Lake, although the lake itself is at an altitude of 10,120 feet above mean sealevel, and portions of the drainage area rise to 10,700 feet. The total area surveyed was 1,774 acres and 64 determinations of depth and density were made. The average depths and densities, classified by elevation, appear in Table 9.

TABLE 9.—*Snow depths and densities in the Sand Lake, Wyo., basin, 1915.*

Number of measurements.	Elevation.	Average depth.	Average density.
	Feet.	*Inches.*	
* 4	10,120	42.75	0.270
10	10,120-10,200	55.20	.237
7	10,200-10,300	60.29	.251
20	10,300-10,400	61.30	.261
5	10,400-10,500	60.60	.260
16	10,500-10,600	60.31	.252
2	10,600-10,700	75.00	.257

* On Sand Lake.

A classification according to slope, or the direction in which the various parts of the drainage face, gives the following results in Table 10:

TABLE 10.—*Snow depths and densities at Sand Lake, Wyo., classified according to slope.*

Slope.	Depth.	Density.
	Inches.	
Northward	64	0.250
Northeastward	62	.270
Eastward	59	.250
Southeastward	55	.270
Southward	52	.230
Westward *	* 35	.090
Northwestward	61	.250
Lake surface	45	0.270

* Based on a single measurement.

A classification according to surface cover gives the following:

	Av. depth.	Density.
In open parks	58 in.	0.259
In timber	61 in.	0.246

The total water content being practically the same in both cases. The results of this survey do not show a uniform increase in density with increase in depth of the total snow layer. The snow cover on the lake, although of less depth than elsewhere, was of greater density.

Nevada.—An intensive snow survey in the Carson and Walker Basin in this State was made in 1914 under the direction of Observer H. S. Cole. The results of this survey are yet in manuscript. In 1916, a series of density measurements were made from Reno as a base station, in cooperation with the University of Nevada. See H. F. Alciatore, (**23**).

THE DENSITY OF NEW SNOW AND OLD GLACIAL SNOW.

One of the most illuminating discussions of snow density available from European sources is that of Dr. Alfred Defant (**25**) of the Austrian Meteorological Institute, who spent a vacation in August, 1908, on the summit of the Sonnblick, 3,095 meters (10,154 feet), making determinations of the density of the snow on Goldberg Glacier.

After describing the apparatus used and the place and manner of the determinations, he says, in part, speaking of a series of density determinations with depth made at two places:

In both series an increase in density with increase in depth is observed and certainly in both cases the density increases to a maximum

at a depth of 87.5 cm. (34.5 inces). Then the density decreases a little and is followed by a second increase. Figures 2 and 3 give a graphic representation of these mean values. [Fig. 2 of Defant here given as fig. 1].

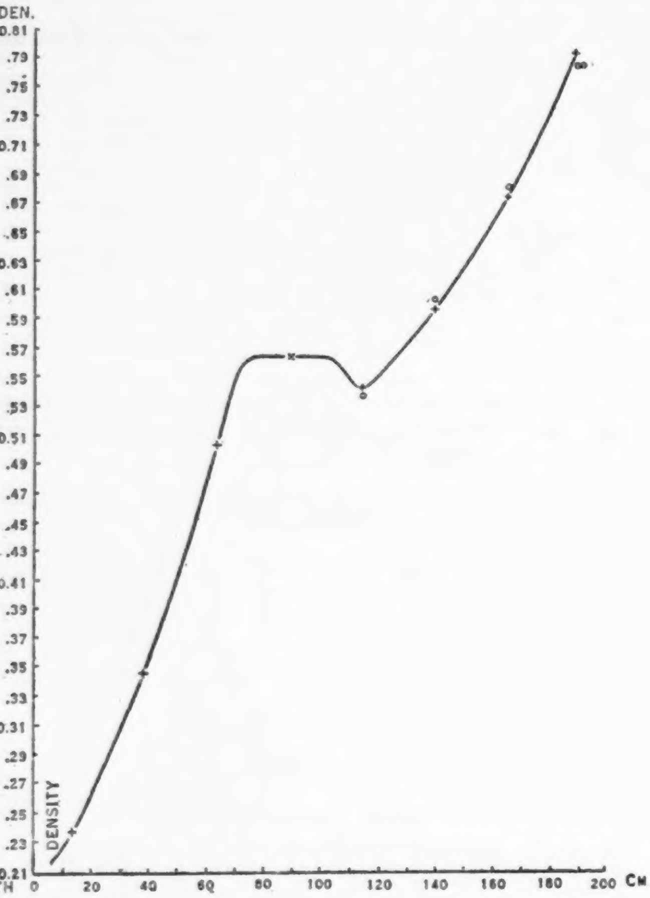

FIG. 1.—Defant's figure 2 showing his curve of relation between depth and density of snow.

In the first series, according to the figure, the maximum density is reached at a depth of 82 cm. (32.3 inches); in the second, at a depth of 70 cm. (27.6 inches). The cause of these mean densities lays in the weather conditions before the measurements were begun. Moderately heavy rains had barely saturated the top layers when they were frozen, forming an ice crust which at most had a thickness of 10 cm. (3.9 inches), hence the rainfall did not soak deeply into the snow. After a somewhat warmer period there followed colder weather and upon the ice crust thus formed there was deposited the fall of an extensive snowstorm, which buried the crust to a considerable depth, separating the old snow from the new. One clearly perceives the difference between the two snow layers. The upper snow layer consisted of light, dazzling upper snow (Hochschnee), which is composed of very small ice crystals, thus forming a mixture of ice and air.

Under the ice crust, on the other hand, the structure of the snow was coarser. The snow was heavier, granulated, and no longer dazzling white, as on the upper layer. We have here pure glacial snow. The size of the grains increased with the depth and, strictly considered, one recognizes that they consist of transparent ice in which many very small air bubbles are inclosed. The top snow has completely lost its crystalline structure, since through frequent thawing the points and needles of the crystals are melted off and the penetrating snow-water collects later about single kernels of ice and is frozen together in larger grains. Measurements enable us to distinguish readily between the fine-grained old snow in the upper layers under the ice crust and the coarse-grained old snow at depths of say about 3 meters. * * *

The increase in density with depth is due to a variety of causes. Freshly fallen snow diminishes in volume when the temperature becomes higher. Snow is made up of an extensive net of capillary tubes, which take up water as a sponge. The air, of which the greater part of a definite volume of snow is constituted, is expelled through the tubes and the density of the snow increases. In the exchange of heat in the surface layers of the snow stratum it is first of all to be considered that the heat is completely used in melting the upper layers and only indirectly exercises an influence upon the lower layers; that the snow-water slowly soaks or filters into the lower layers. On the contrary during the prevalence of cold, when it continues for a time, it gradually penetrates deeper and deeper into the layers, until finally it penetrates the deepest and not as the heat which is fully consumed on the surface.

Another cause of the increasing density of the snow with depth is the pressure which in the upper snow layers exercise upon the lower. The volume of the snow becomes the smaller, the greater is the pressure which weighs upon them. The air is squeezed out and the density *increases*. * * *.

In the analytical presentation of the subject of snow density as dependent upon depth, most authors nearly always assume that the density increases proportionately to the depth and that when $\rho=$ the density of the snow, $z=$the depth counting from the snow surface, then the increase in density will be represented by the formula

$$\rho=\rho_0+az.$$

An inspection of our graphic presentation [fig. 1] shows directly that this relation is not fulfilled, surely for the upper layers. The increase follows a curve slightly concave to the axis of ordinates and can not therefore be represented by a linear relation.

A logarithmic relation, first derived by Abe [10] gives values, as we shall see, which better agree with the actual observed values. If we designate by p the pressure of the snow cover in the depth z, then

$$\rho dz=dp.$$

Assume further that the density of the snow is proportional to the pressure of the overlying stratum of snow, then

$$\rho=\rho_0+kp,$$

where ρ_0 is the density at the surface and k is a constant. From these two equations for ρ we can eliminate p and we then have

$$kdz=\frac{d\rho}{\rho}.$$

If ρ_0 is the density at the surface it follows that

$$\log\rho=\log\rho_0+kz.$$

These relations were employed in the four branches of our curve [fig. 1], and gave for the increase of the density with depth the following:

For [fig. 1] applicable from $z=0$ to $z=80$

$$\log\rho=\log 0.2404+0.00529\ z$$

For [fig. 1] applicable from $z=162.5$ to $z=312.5$

$$\log\rho=\log 0.4863+0.00025\ z$$

For figure 3 [not reproduced] applicable for values of z between 0 and 70,

$$\log\rho=\log 0.3198+0.00201\ z.$$

These four equations represent the branches of the curves with great precision; indeed, the departures of observed and computed values are well within the error of observation.

THE DIMINUTION OF A SNOW COVER.

It is well known that a snow layer, especially if composed of freshly fallen snow, diminishes in depth rapidly at first, then at a much slower rate. The amount of shrinking in 24 hours varies, of course, in accordance with the prevailing atmospheric conditions. A high wind, for example, will not only drift freshly fallen snow, but will compress the superficial layer even where there is no drifting. Many examples of the compression or packing of snow by high winds were observed by the writer at Mount Weather, Va., during the winters of 1909–10, 1910–11, and 1911–12, but no quantitive values as to the amount of the compression were secured. The snowfall observer at Government Camp, Oreg., in the Cascade Mountains, reports a shrinkage of 16 inches in 24 hours on January 15, 1916, with a high wind and a daily mean temperature of 9°F. This value is, of course, exceptional, but many well-attested cases are at hand wherein the shrinkage was from 4 to 6 inches. At the height of the melting season the disappearance of snow by melting sometimes reaches the high value of about 8 inches daily (**26**).

[10] Meteorol. Ztschr., 1908, 25, 461.

Dr. J. Westmann (8) briefly discusses the shrinkage of a snow cover at several points on the public square in Upsala, separated from each other by short distance. He selected a place where the snow cover was fairly uniform and had a depth of approximately 20 cm. (7.8 inches). Ten measurements were made at points distant from each other about 3 meters (9.8 feet) and the mean of these 10 measurements was adopted as the mean depth for the time and place. Continuing these measurements over a period of 12 days in March, 1901, during which time thawing weather did not prevail, he was able to accurately note the diminution of the snow cover day by day. Another series of measurements was made in snow that had been shoveled together in which the total depth was at one time 54 cm. (21.2 inches). The average temperature during the period was 31.1°F. The diminution in depth of the snow cover was greatest in the snow that had been piled together artificially, the maximum decrease recorded in 24 hours being 4.8 cm. (1.9 inches). Where the snow lay as it fell, the maximum decrease recorded in 24 hours was 3.93 cm. (1.53) the average daily decrease being 1.28 cm. (0.5 inch).

Dr. Westmann considers the loss due to evaporation as being of small importance and points out that in some cases the gain by condensation more than balances the loss by evaporation.

The water content of the snow was determined by weighing a known volume taken from the same points at which depth measurements were made. Two series of density determinations were made, the first for a top layer of 12 cm. (4.7 inches) and the other for a layer of 6 cm. (2.4 inches) next to the earth's surface. The results show, as was to be expected, that the density increases with the depth.

Dr. Westmann also points out that the water equivalent of the snow cover, which was 70 mm. on March 10, had diminished to 30 mm. on March 23. He considers the loss of 40 mm. to have been due to melting snow, the greater portion of which flowed away. During the melting the structure of the snow changes essentially, the ordinary snow becomes changed into angular grains, when the adhesion between these grains becomes small through intense melting, the structure of the snow becomes as coarse sand.

The same author in collaboration with M. Jansson discusses at length and in great detail the several influences contributing to a diminution in depth of a snow layer. (See p. 105.)

GROWTH, SETTLING, AND FINAL DISAPPEARANCE OF A SNOW COVER IN THE SIERRA NEVADA, 1915-16.

By HENRY F. ALCIATORE, Meteorologist.

[Dated: Weather Bureau, Reno, Nev.—,1917.]

The following is a brief account of the controlling factors which determined the growth, settling, melting, and final disappearance of the snow cover of the 1915-16 season at four typical Weather Bureau mountain snowfall stations in the Lake Tahoe watershed. The stations selected were: Tahoe and Tallac, Cal., on the west side, and Marlette Lake, Nev., and Bijou, Cal., on the east side of the lake. All of these, except Marlette Lake, are on the shores of Lake Tahoe. Marlette Lake is a small body of water about 1,700 feet above the surface of Lake Tahoe, 2 miles east of the latter.

The season opened with a general snowstorm, November 8, 1915. November, January, and May were colder than usual, but February, March, and April were quite mild, particularly February. If in the absence of humidity, wind, and sunshine data for the places named, we consult the records of the nearest Weather Bureau observatory, namely, those of Reno, Nev., we find that from March to June the weather was unusually dry and windy and the amount of insolation considerably above the normal for the season, yet, in spite of these conditions, the snow cover finally disappeared at about the usual time of year at Marlette Lake, and somewhat ahead of time at the other stations.

Speaking generally, if we exclude impurities, a snow cover consists of two elements, and only two, i. e., snow and air. As a rule, fresh snow contains more air than snow, and the reverse of this holds true for the lower layers of a snow cover. For example, at one point in the Carson watershed, the snow was 10 feet deep, and its average density was 40 per cent; hence a cylinder of that snow, of one square foot base, would have contained about 6 cubic feet of air, and only 4 cubic feet of snow.

The details of the topography, geographical location, etc., of each station whose records have been used in this paper will be found in Table 11. The first three are on the lake shore, while the fourth, Marlette Lake, is 1,670 feet above the lake surface, and about 2 miles inland, on the eastern part of the drainage basin of the lake.

TABLE 11.—*Location of mountain snowfall stations.*

	Altitude.	Latitude. (N.)		Longitude. (W.)	
	Feet.	°	′	°	′
Tahoe, Cal	6,230	39	9	120	12
Tallac, Cal	6,230	38	56	120	2
Bijou, Cal	6,230	38	57	119	58
Marlette Lake, Nev	7,900	39	10	119	55

As pointed out by Prof. Henry for the high Sierras of central California (**27**), so in the Tahoe Basin the fact that a considerable portion of the snow on the ground in midwinter settled or packed through natural causes aside from the occurrence of warm weather attended by rain is evident. In fact, the greatest amount of fortnightly settling at any station, namely, at the rate of 7.2 inches per day (Marlette Lake) occurred in January, the coldest month of the season, and one of the coldest on record. The average daily settling of the snow cover for the entire season, in inches, was 2.2 inches at Tahoe, 1.6 at Tallac, 1.5 at Bijou, and 1.7 at Marlette Lake. Comparing these values with the corresponding ones given by Henry for Fordyce Dam, Summit, and Tamarack, Cal., for a period of years, which were 1.9, 2, and 2 inches, respectively, we note that Tahoe, Cal., at an altitude of 6,230 feet, shows a slightly greater rate (in 1915-16) than the average rate given for Tamarack. The most pronounced settling occurred at all stations in the Tahoe Basin in January, the month of heaviest snow; at Tallac, in February, a month of scant snowfall.

Table 11 below has been prepared to show the daily changes in depth of snow cover at a single station in the Tahoe Basin for the period November 9 to December 31, 1915. The amount of snow, as it fell day by day, has been entered in the second column and the total depth of the snow cover on the ground is given in the third column each day. It will be readily seen that the

depth on the ground diminishes quite steadily and irregularly. Thus, on November 9, a total cover of 31 inches of freshly fallen snow was on the ground. That amount diminished until, on the 22d, there were but 3 inches remaining. Further details become apparent by an inspection of Table 12.

TABLE 12.—*Daily depths of the snow cover at a single station in the Lake Tahoe Basin, November-December, 1915.*

Date.	Snow.		Daily change.	Date.	Snow.		Daily change.
	Depth of fall.	Amount on ground.			Depth of fall.	Amount on ground.	
1915.	*Inches.*	*Inches.*	*Inches.*	1915.	*Inches.*	*Inches.*	*Inches.*
Nov. 8	2.0	0		Dec. 6		7.0	− 1
9	29.0	31.0		7		6.0	− 1
10		24.0	− 7	8		5.0	− 1
11		18.0	− 6	9		4.5	− 1.5
12		15.0	− 3	10		3.0	− 1.5
13		14.0	− 1	11	1.0	4.0	+ 1
14		13.0	− 1	12		3.0	− 1
15		11.0	− 2	13	9.0	12.0	+ 9
16	2.0	9.0	− 2	14	20.0	32.0	+20
17		8.0	− 1	15		29.0	− 3
18		7.0	− 1	16		24.0	− 5
19		6.0	− 1	17		22.0	− 2
20		4.5	− 1.5	18		19.0	− 3
21		4.0	− 0.5	19		19.0	0
22		3.0	− 1	20		18.0	− 1
23	3.5	6.5	+ 3.5	21		18.0	0
24		6.5	0	22		17.0	− 1
25		6.0	− 0.5	23		16.0	− 1
26		6.0	0	24		15.0	− 1
27		5.5	− 0.5	25	1.0	16.0	+ 1
28		5.5	0	26		16.0	0
29		5.0	− 0.5	27		15.0	− 1
30		3.0	− 2.0	28		15.0	0
Dec. 1		3.0	0	29	1.0	16.0	+ 1
2		2.0	− 1	30		16.0	0
3	10.0	12.0	+10	31		16.0	0
4		11.0	− 1				
5		8.0	− 3	Total	78.5		

The mean monthly temperature, the departure from the normal, together with the amount of settling and melting, and percentage decrease of snow cover for stations for which records are available, are given by months in Table 13.

The figures in the next to last column were obtained by adding to the depth of snow on the ground on the first day of the month the total snowfall during the month and subtracting from the sum thus obtained the amount of snow which remained on the ground at the end of the month. For example: Tahoe City, Cal., December 1915, total fall during month=42 inches; on ground, first of month=3 inches; total=45 inches; on ground at end of month=16 inches, therefore amount of settling or disappearance during the month=29 inches (See Table 12).

The values in the last column of Table 13 illustrate the difference between losses of snow by settling and by melting. For example, in January the losses by settling were:

51 per cent at Tahoe.
41 per cent at Tallac.
47 per cent at Bijou.
55 per cent at Marlette Lake.

In April the losses by melting (actual disappearance) were:

97 per cent at Tahoe.
100 per cent at Tallac.
100 per cent at Bijou.
36 per cent at Marlette Lake.

TABLE 13.—*Mean temperature and departure from normal, and loss of snow by settling and melting.*

Months.	Mean temperature.	Departure from normal.	Amount of settling and melting.	Loss by settling and melting.
Tahoe, Cal.				
	°F.	*°F.*	*Inches.*	*Per cent.*
November	35.7	−1.3	33	92
December	29.4	−1.4	29	65
January	22.5	−4.5	129	51
February	34.6	−6.6	72	49
March	35.4	−2.4	56	58
April	40.0	−3.0	56	97
Tallac, Cal.				
November	39.6	−0.6	1	100
December	31.0	−2.0	26	79
January	23.6	−6.4	66	41
February	31.6	−0.6	86	74
March	38.6	−1.6	38	56
April 1-17	44.2	−3.2	30	100
Bijou, Cal.				
November	40.8	−1.2	9	100
December	32.2	−1.2	17	59
January	25.6	−4.4	67	47
February	33.4	−4.4	57	56
March	39.8	−4.8	45	70
April 1-20	45.0	−6.0	19	100
Marlette Lake, Nev.				
November			16	76
December			42	58
January			125	55
February			63	45
March			27	26
April			28	36
May			44	79
June 1-6			12	100

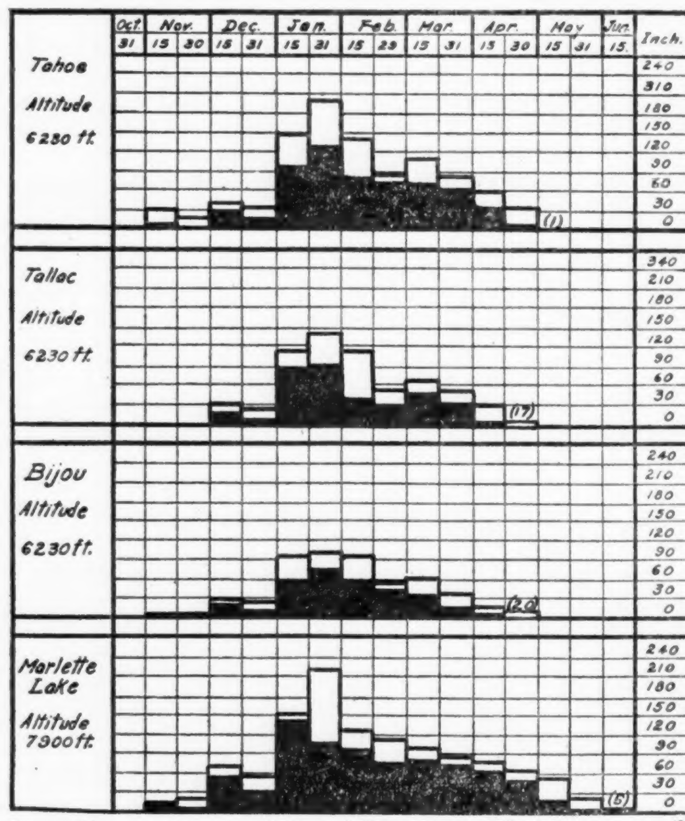

FIG. 2.—Diagrams of growth, settling, and disappearance of the snow cover over the Lake Tahoe Basin, 1915-16.
Shaded areas show depth; unshaded areas within heavy line show amount of settling or melting. Small figures in ( ) give date of disappearance of last snow.

The records of three stations covering the snowfall conditions of the last three seasons have been examined, to ascertain whether the thickness of the snow cover at time of its maximum depth for the season and the time of final disappearance were related; as to Tahoe and Bijou, the results were negative; at the high-level station, however, such a relationship was observed, as may be gathered from Table 14.

TABLE 14.—*Showing relation of depth of maximum snow to date of final disappearance at Marlette Lake.*

Year.	Date of maximum depth of cover.	Depth.	Date of final disappearance.
		Inches.	
1914	Jan. 24	158	June 9
1916	Jan. 18	141	June 6
1915	Feb. 11	84	June 3

Referring to figure 2 we note that the settling of the snow was more gradual at Marlette Lake than at the shore stations; also that on May 31 at the close of the season the depth of snow on the ground at that place was normal, i. e., 12 inches.

DENSITY OF SNOW COVER AT BUMPING LAKE, WASH.

Table 15 presents a series of weekly measurements of the density of the snow cover at Bumping Lake, Wash., together with a record of the temperature and precipitation during the time the density measurements were made. The measurements were made by Mr. J. H. Nelson, of the U. S. Reclamation Service.

This table is of special interest since it enables one to note the march of snow density with the season and to observe the apparent effect of the changing weather conditions on the water content of the snow cover. The weekly depths and densities of the snow cover, as given in the table, are the means of 10 separate measurements.

Columns **2** and **3** of Table 15 refer to the snow layer at the time stated in the first column. Columns **4**, **5**, **6**, **7**, **8** and **9** refer to the current weather conditions of the week. The data in column **10** total possible water available, is obtained as follows: For example ending November 16, 1914, the average depth of the snow layer was 17.5 inches and the density of the layer was 0.151 therefore $17.5 \times 0.151 = 2.54$ inches, the water content of the snow. To this amount is added the total precipitation as snow during the week as entered in column **5**, viz, 2.52 inches, making the water available had none been lost, 5.16 inches. Column **11** is simply the gain or loss week by week as shown by the entries in column **10**.

Considering these weekly values of available water, it is noted, as might easily by inferred, that there is a continual oscillation up and down. The apparent lack of control exerted by the weather conditions on the water content of the snow layer, or more precisely the lack of accord between the water precipitated and that which later appears in the snow layer, was not expected. Some further explanation will perhaps make our meaning clear.

TABLE 15.—*Average depth and density of snow cover and atmospheric conditions during its life, at Bumping Lake, Wash.* (*U. S. Reclamation Service*)

Week ending—	Snow layer.		Precipitation during week.			Temperature.			Water available, total possible.	Gain or loss.	Week No.
	Average depth.	Density.	Snow.	Water equivalent.	Total, rain and snow.	Mean maximum.	Mean minimum.	½ [7+8].			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1914.	*Inches.*		*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	*Inches.*	*Inches.*	
Nov. 16	17.5	0.151	27.0	2.52	2.85	41.1	27.0	34.0	5.16	....	1
23	10.1	0.212	T.	0.0	0.38	38.7	23.7	31.2	2.52	−2.64	2
30	8.0	0.221	1.0	0.21	0.21	42.0	27.0	34.5	1.98	−0.54	3
Dec. 7	13.0	0.178	9.5	0.37	0.37	32.9	22.9	27.9	2.68	+0.70	4
14	11.7	0.196	3.0	0.19	0.19	25.7	9.0	17.3	2.38	−0.30	5
21	11.0	0.216	T.	T.	T.	26.7	−0.5	13.1	2.38	0.00	6
28	21.0	0.172	16.0	1.12	1.12	36.7	18.7	29.7	4.73	+2.35	7
1915.											
Jan. 4	21.4	0.206	5.5	[a] 0.73	0.73	35.4	22.6	29.0	5.13	+0.40	8
11	31.9	0.174	20.5	1.56	1.56	34.1	23.6	28.8	7.11	+1.98	9
18	37.8	0.202	18.0	1.57	1.57	35.4	14.0	24.7	9.20	+2.09	10
25	33.0	0.226	0.0	0.0	0.0	29.6	−1.6	14.0	7.46	−1.74	11
Feb. 1	31.4	0.240	12.0	0.84	0.84	36.9	15.1	26.0	8.38	+0.92	12
8	45.2	0.225	17.5	1.72	1.72	35.9	22.0	28.9	12.09	+3.71	13
15	41.4	0.246	1.0	0.09	0.09	40.0	11.1	25.5	10.27	−1.82	14
22	39.0	0.273	8.0	0.87	0.87	38.1	24.9	31.5	11.51	+1.24	15
Mar. 1	36.5	0.302	3.5	0.61	0.61	41.7	25.7	33.7	11.63	+0.12	16
8	33.4	0.329	T.	[a] 0.36	0.36	44.6	24.3	34.4	11.34	−0.29	17
15	28.8	0.350	T.	T.	1.77	44.4	27.4	35.9	11.85	+0.51	18
22	22.7	0.354	T.	T.	0.14	56.6	24.3	40.4	8.17	−3.68	19
29	17.2	0.366	0.0	0.0	0.07	48.3	28.9	38.6	6.36	−1.81	20
Apr. 5	9.8	0.329	0.0	0.0	2.77	49.3	31.4	40.3	5.99	−0.37	21
1916.											
May 15	43.4	0.396	9.0	[a] 1.28	1.28	50.7	27.3	39.0	18.46	....	....
29	17.7	0.406	0.0	....	0.46	51.1	32.6	41.8	7.64	−10.82	....

[a] Partly rain.

On the whole, the season of 1915–16 appears to have been one of deep snows with an uncommonly thick covering of snow on the ground most of the time, but not otherwise remarkable. Lake Tahoe reached its maximum summer level July 14, which is about 13 days later than the 7-year mean date. Since 1910 the maximum summer levels have occurred 3 times in June and 4 times in July. It seems that when the seasonal snowfall is above the average the lake is more likely to crest in July than in June.

The first entry in the table, viz, the record for the week ending November 16, 1914, shows that the depth of the snow layer was 17.5 inches with a density of 0.151. Just before the beginning of the snow there had been a rain of 0.33 inch and only a few days previous, there had been heavy rains so that while the ground was bare it was doubtless well saturated and unfrozen, a condition not favorable to the immediate absorption of any snow that might melt during the daylight hours. The total depth of the snowfall during the week, was 27.0 inches and it had lain on the ground about 48 hours. In that time there was a diminution in depth of 9.5 inches. The water equivalent of this snow, assuming that its density was the same as when it fell, must have been about 0.88 inch, therefore if no evaporation had taken place the density of the remaining snow should have increased by at least that amount. In the beginning, the density was 0.093. On November 16, it was 0.151, an increase of 0.058 which multiplied by the total depth, 17.5 inches, gives 1.01 inches as the total increase, or a net increase of 0.13 inch. These computations seem to indicate a melting of the top layers of the snow and the retention of the melted snow in the snow layer.

Continuing a similar comparison for the succeeding week, it is noticed that the depth of the snow layer has diminished from 17.5 to 10.1 inches; that there was no snow during the week but that a rain of 0.38 inch fell. The increase in density was from 0.151 to 0.212 or about 6 per cent and this would be equivalent to 0.61 water. The loss of water content during the week on account of diminution of depth, was however 2.64 inches, hence it is evident that the increase in density of the remaining snow layer only partly accounts for the loss of water here noted. During the third week there was a further loss in the water content of the snow although a small amount of fresh snow was added to the old snow. During the fourth week of the record there was a fall of 9.5 inches of fresh snow of rather low density. The depth of the old layer was increased by 2 inches, the density however, suffers a diminution and the water available shows a small increase. A fall of 3 inches of snow and prevailing low temperatures evidently checked the loss of water during the 5th and 6th weeks. During the next 4 weeks, viz, December 28 to January 18 inclusive, there was a fall of 60 inches of snow which resulted in an increase in the snow cover from 11 to 37.8 inches; there was also a slight increase in density and the available water increased from 2.38 to 9.20 inches or 6.82 inches, an amount that is greater by 1.84 inches than the increment of water precipitated as snow during the same time. A small part of this increase may be ascribed to the rain which fell on January 4, but the greater part of it remains unexplained.

The eleventh week was one of low temperature, no precipitation, and one altogether favorable to the conservation of the snow cover, yet it suffered a diminution of 4.8 inches in thickness and a loss in total water content of 1.74 inches. The increase in density amounted to about 2 per cent, not nearly enough to offset the loss due to the shrinking of the snow layer. Then followed two weeks of fairly heavy snowfall, resulting in the greatest depth of the winter, viz, 45.2 inches, with a total water content of 12.09 inches. From this point onward the depth diminished and the density increased rather steadily, the greatest density of the season being reached during the week that ended March 29, when, with a thickness of 17.2 inches, the density was 0.366. With a further diminution in depth to 9.8 inches the density fell to 0.329. *It seems probable that some water escapes to and is absorbed by the ground when the thickness of the snow layer is reduced to, say, less than 10 inches.* The diminution in density when an increase should have occurred, here observed has also been noted in the records for other stations, but it is evidently not a general phenomenon.

The two entries for 1916 are the only ones available for that year. They also show that the increase in density with age of the snow cover does not approach in any way the loss of possible water due to shrinking of the snow cover; thus the density of the snow cover increased but 1 per cent in the two weeks separating the measurements, whereas the depth diminished 25.7 inches.

A suggestion as to what becomes of the water represented by the shrinkage of the snow cover is found in a paper by Mr. Robert E. Horton (**10**), wherein it is shown that the percentage of precipitation appearing later as run-off in streams, varies very greatly during the winter and late spring months. In the case of West Canada Creek, of New York, during the winter of 1903–4, the run-off varied from 12.35 per cent in December, 1903, to 329.6 per cent in April, 1904.

Just how much water passes into the atmosphere by evaporation from a snow cover for the dry region west of the Rocky Mountains is not yet certain.

EVAPORATION OF SNOW.

European observations on the subject of the evaporation of snow generally seem to indicate that the amount of evaporation from a snow layer is small. Observations by Westmann (**8, 9**) point to a daily maximum value of 2 to 3 mm. (=0.08 to 0.12 inch) under favorable conditions. He remarks on the experiments:

> We have attempted to measure the evaporation of a snow cover in the following manner: Some slices of snow 15.5 by 22 cm. square on the surface and about 4 cm. high were cut out and placed in basins of the same dimensions. The basins, with white enameled inside surfaces, were placed in the snow cover in such manner that the surface of the snow contained was in the same plane as the surface of the surrounding snow cover. It may be assumed that the evaporation and condensation were the same at the surface of the snow in the basins as at the surface of the surrounding snow cover. To measure the evaporation, the basins were weighed each day at noon during the month of February and the larger part of March. Afterwards the measurements were generally more frequent, the samples of snow having to be renewed because of the ease with which they liquified, because of the warm weather and strong insolation. Often it was impossible to avoid melting. The evaporation measured was then the sum of the evaporation of the snow which remained and of the water from the melted snow. The measurements of evaporation in March and April, being in part affected by this error, do not represent, it is true, the evaporation of snow, but are the higher limits of this quantity, and thus have a certain value, since these limits are very low.

SUMMARY.

It seems well established that the density of fresh snow is least in midwinter and greatest in late spring and that, in general, the density increases with the temperature, but the tendency for precipitation to occur in the form of rain or sleet with temperatures above freezing adds to the uncertainty of density measurements when the air temperature is above freezing. It is believed that the error in density measurements with surface temperatures above 32°F. is greater and more frequent than is generally supposed.

The density of a snow cover, other circumstances as to weather being equal, is fairly uniform, as shown by the intensive snow surveys made in the West within the last few years. It seems well established, however, that, due to basic climatic differences, higher densities are to be expected in the Northeastern States than in the semiarid States of the West and Southwest.

There is urgent need of accurate determinations of the loss of snow by evaporation in the Far West of the United States, and also of discharge measurements in one or more basins in order to gage the run-off from melting snow and the contemporaneous precipitation. There is also need of a record of the inclusive dates between which the soil is frozen, and particularly as to whether or not the soil is frozen at the time the first enduring snow cover of the season covers the soil.

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A MODERN CHINESE METEOROLOGICAL MONTHLY.

In the MONTHLY WEATHER REVIEW for May, 1916, Mr. Co-Ching Chu[1] referred to a monthly magazine for astronomy, seismology, and meteorology, published in China. Very recently he kindly sent the editor a sample copy, viz, the issue for December, 1916, which it seems worth while to notice briefly here.

This new journal, whose first number appeared in July, 1915, bears the title "Journal of Meteorology and Astronomy" and is published at Peking by the Central Observatory of the Department of Education. Its front cover, which is the usual left-hand cover page of European journals, measures 25½ by 18 centimeters and is wholly in Chinese character ornamented with an equatorial orthographic projection of the Atlantic-Afric hemisphere having the meridian of Greenwich as the central meridian. The choice of hemispheres was, perhaps, influenced by the astronomical bent of the journal. Following the 14 pages of advertising in colored inks we find in the December, 1916, issue of volume II, 42 pages of matter on meteorology and astronomy followed by 100 pages (independently paged) of astronomical tables.

All the pages are numbered from left to right and, consistently, the text matter is arranged in lines reading from left to right instead of in vertical columns reading downward from right to left. The first 20 pages of the text are devoted to brief papers each independently paged, on astronomical and meteorological subjects, the issue before us containing an illustrated paper on the observation and measurement of cloud altitudes. All the illustrations here are from French sources only, which reminds us that the chief meteorological editor of the journal, Mr. Pin-Jen Chang, received his European education in France.

Pages 21 to 42, inclusive, begin with graphs of pressure, temperature, relative humidity, and winds at the Central Observatory, Peking, for the month in hand, in this case November, 1916. These are followed by daily values at Peking for the following elements:

Pressure: Mean, maximum, minimum, range (mm).
Temperature: Mean, maximum, minimum, range, for air (°C).
Precipitation (mm).
Clouds: Amount (per cent).
Winds: Direction, force (1–8).
Humidity: Relative; vapor pressure (mm.).
Ground temperatures at depths of 30 cm., 60 cm., 100 cm.; etc. (°C.).
Ground water temperature (°C.).
General notes on the weather and sky (international meteorological symbols).

The next 16 pages contain shorter tables giving daily morning and afternoon observations of: Pressure; temperature; relative humidity; wind, direction and force; state of the sky or weather at the following stations:

Name.	Longitude (E.).		Latitude (N.).		Name.	Longitude (E.).		Latitude (N.).	
	°	′	°	′		°	′	°	′
Amoy	118	06	24	28	Changsha	112	46	28	13
Swatow	116	40	23	21	Hankow	114	20	30	32
Ningpo	121	42	29	57	Wenchow	120	37	28	00
Chingkung	119	26	32	10	Pehai	109	04	21	28
Kiukiang	116	06	29	42	Ichang	111	21	30	40
Newchwang	122	36	40	58	Langpo	127	30	51	00
Chefoo	121	25	37	32	Wuchow	110	26	23	32
Shami	112	55	23	10	Chungching	106	35	29	29

[1] "The Chinese Weather Bureau," MONTHLY WEATHER REVIEW, Washington, May, 1916, 44: 289.

It would appear that we here have to welcome a Chinese journal, well supported, that is making a determined effort to introduce the best meteorological methods to the people of China and to give them, as well as Europeans, prompt publication of the observational results from the affiliated Chinese observers. The character of the contributions to the journal may necessarily be less advanced in treatment for a few years, but they will undoubtedly reflect the growth of meteorological knowledge and interest in China, and it is the sincere wish of the United States Weather Bureau that the Peking Journal of Meteorology and Astronomy will long continue to be the worthy representative of China's increasing interest in meteorological subjects.

In closing, it only remains to emphasize the desirability of the Journal publishing résumés of its important contributions in a western language.—C. A., jr.

METEOROLOGICAL OBSERVATIONS ON U. S. LIGHTSHIPS.

By H. E. WILLIAMS, Meteorologist in Charge.

[Dated: Weather Bureau, Washington, D. C., May 1, 1917.]

The maintaining of special meteorological stations on lightships is a new departure in United States Weather Bureau work, the service being recently established.

Several attempts had been made by the Bureau to secure reports from light vessels off the Atlantic coast, notably the one off Cape Hatteras, but without success. On September 18, 1915, the Secretary of Commerce addressed a letter to the Secretary of Agriculture informing him that an appropriation was available for a first-class light vessel on Nantucket Shoals, Mass., and asking if the Weather Bureau would be interested in obtaining observations and reports from this station, and also informing the Secretary that in September, 1912, "arrangements were made at the request of the Navy Department for certain weather observations to be made on this vessel, such observations being broadcast from the vessel by radio three times each day." Subsequent correspondence developed the fact that the observations for the Navy Department consisted of the state of the weather, direction and force of the wind, and character of the sea.

The foregoing offer was accepted by the Weather Bureau, and subsequently permission was obtained to establish stations on three other lightships, making a total of four which were established, as follows:

Diamond Shoals Lightship No. 71, N. C., to date March 10, 1916 (Instructions 87, 1916);

Frying Pan Shoals Lightship No. 94, N. C., to date April 22, 1916 (Instructions 39, 1916);

Nantucket Shoals Lightship No. 85, Mass., to date August 19, 1916 (Instructions 87, 1916);

Heald Bank Lightship No. 81, Tex., to date November 1, 1916 (Instructions 87, 1916).

The equipment consists of 1 marine barometer, 3 exposed thermometers, 2 anemometers, and 1 single-register.

Two observations are taken each day and radiographed to the nearest land station, and thence by telegraph to Washington. The usual elements are observed, except the rainfall is not measured.

The designation of the observers is "Observers lightship," and they receive pay at the rate of 25 cents for each observation.

The establishment of meteorological observatories on United States lightships described above is the latest phase in the utilization of these marine outposts for the benefit of United States sea traffic. As soon as the commercial success of wireless communication was evident the Weather Bureau began to arrange for the distribution of forecasts to outgoing and incoming ships by that method from conveniently located lightships, and the system was in action by July, 1902.[1] European weather services had established meteorological instruments on the lightships in the Baltic, the North Sea, and elsewhere as early as about 1900.

It is to be anticipated that the anemometer observations thus to be secured by a registering and recording instrument will be of the greater interest to the student of atmospheric mechanics and dynamics.—C. A., jr.

AVALANCHE WIND AT JUNEAU, JANUARY 26, 1917.

By M. B. SUMMERS, Meteorologist and Section Director.

[Dated: Weather Bureau, Juneau, Alaska, Feb. 19, 1917.]

An avalanche wind occurred near Juneau, Alaska, on January 26, 1917, at 9 a. m., as the result of a heavy snowslide into Gold Creek Gulch.

An unusual amount of snow had accumulated on the slope of Mount Juneau, which has an east-west trend and an altitude of about 3,500 feet. The southern slope is quite precipitous and at its foot is a narrow ravine or gulch. Winding along the opposite or southern bank of this ravine at about 50 feet above the floor is a roadway with a heavy plank walk along its outer edge. Just below the plank walk, yet some distance above the bottom of the ravine stood three cabins. These cabins happened to stand just opposite the 150 feet broad section of the north bank where the snowslide occurred. The force of the blast generated by the downrushing snow was sufficient to completely demolish the cabins and their débris was carried 100 feet up the slope in company with the 4 by 4 inch timbers and 12 by 2 inch cross planks of the walk. Another indication of the force of this wind is given by a large piece of concrete cement chimney which was also carried up the slope with as much apparent ease as were the other fragments. It appears that the wind had a lateral as well as a forward component, as was evidenced by the destruction of a cabin 500 feet down the gulch in the direction of Juneau, the edge of the city being only about a quarter of a mile away. The force of the wind was felt throughout the city, and carried with it a blinding whirl of snow that came with a suddenness that was startling and that enveloped the city in a pall of semidarkness for several minutes. Unfortunately the Weather Bureau anemometer had not yet been installed, and the velocity is therefore not known.

It should be borne in mind that the snow did not pile up on the opposite side of the gulch and that it did not at any point touch the buildings that were demolished. The destruction wrought was due entirely to the force of the wind generated by the great velocity of the slide as it neared the bed of the gulch.

Photographs showing the appearance of the slide and the resulting damage are inclosed. These were taken in the afternoon about five hours after the phenomenon occurred and during which interval nearly an inch of snow had fallen, thus rendering the débris less conspicuous than would otherwise have been the case.

Two other slides occurred on the same slope during the same forenoon and within a mile of the one above described. In one of these two men who were working on an electric transmission line lost their lives.

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[1] *See* G. W. Smith in this REVIEW, 1914, 42 : 544.
Also footnote to article by Dr. P. Polis in this REVIEW, December, 1908, 36 : 407.

TORNADO AT CINCINNATI, OHIO, MARCH 11, 1917.

By WILLIAM CHARLES DEVEREAUX, Meteorologist.

[Dated: Abbe Meteorological Observatory, Cincinnati, Ohio, Mar. 21, 1917.]

The first well-defined tornado in the city of Cincinnati, of which there is an authentic record, occurred during the evening of March 11, 1917. The preceding disastrous storm of July 7, 1915, was not classed as a true tornado although there is some evidence that it was a gyratory storm but on a comparatively large scale.

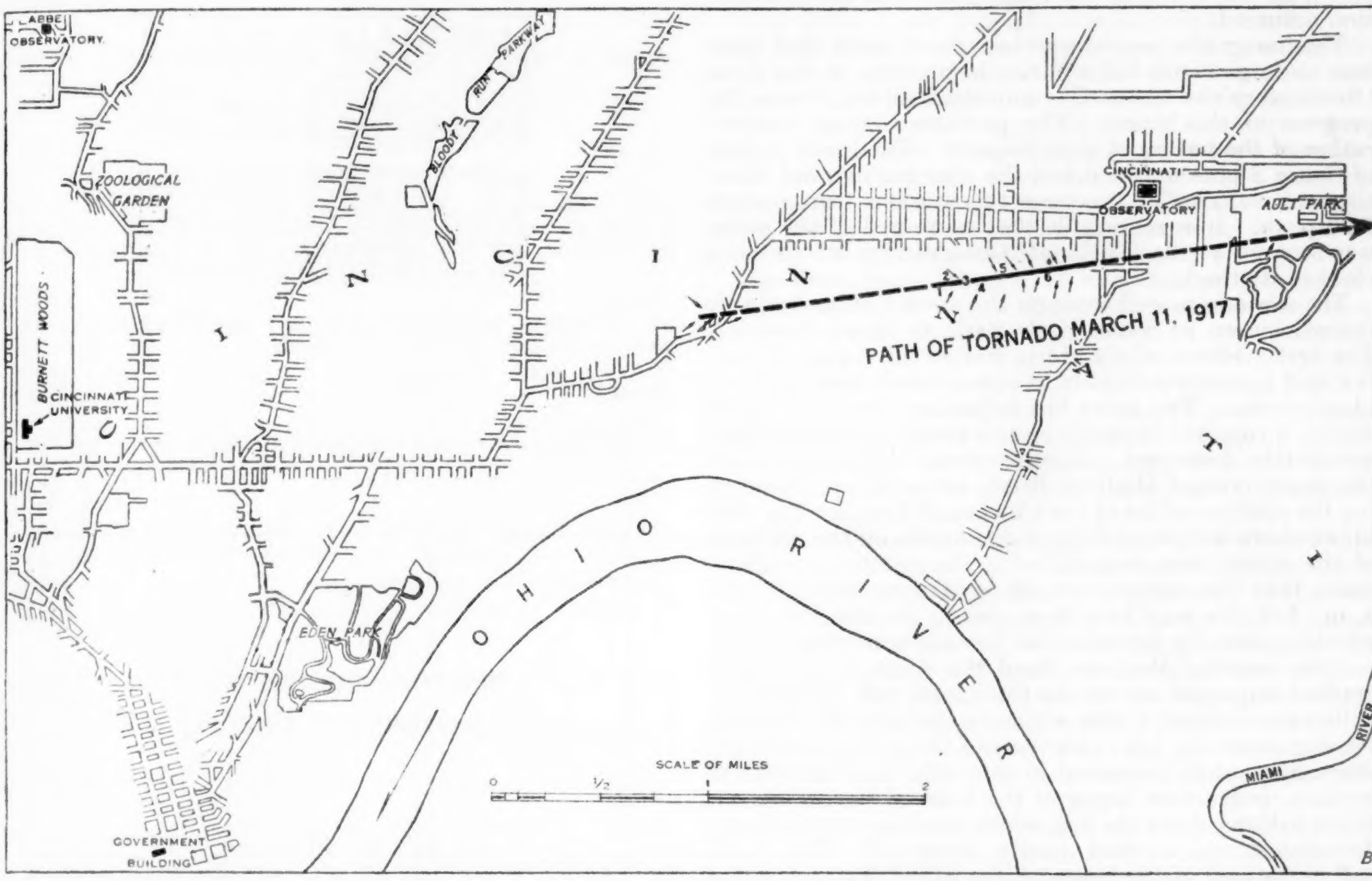

FIG. 1.—Skeleton plat of the portion of Cincinnati visited by the tornado of March 11, 1917, showing the track of the storm and the location of significant points. (Top of map is north.)

The thunderstorm.—During the afternoon of March 11, 1917, the weather was unseasonably warm with a light southwest wind and an overcast sky. The weather map made from the observations taken at 8 p. m., 75th meridian time (7 p. m., local standard time), showed an area of low pressure over the lower Lakes Region with a trough of low pressure extending southwestward across the Ohio Valley close to but slightly northwest of Cincinnati. At the time of observation a thunderstorm was approaching the city from the west, and a light rain was falling. The thunderstorm was over the western portion of the city from about 6:50 p. m., to 7 p. m., local time, and over the central portion of the city from 7 p. m., to 7:12 p. m. The lightning flashes were bright but the storm was not specially severe. About 7 p. m., the barograph trace at the Abbe Meteorological Observatory showed that the pressure fell sharply 0.08 of an inch and rose sharply 0.09 of an inch, and similar but somewhat smaller changes occurred at the Government Building (fig. 2). These changes were of the usual type of pressure changes attending the passage of a thunderstorm, and no other unusual changes in the pressure occurred at either station during the evening. At 7:11 p. m. the electric lights went out in the northern portion of the city, after a sharp flash of lightning which burnt out a transformer. The thunderstorm moved off to the east and lightning was observed in that direction during the following hour. The highest wind velocity recorded was 25 miles per hour at the observatory from 7:09 p. m. to 7:12 p. m., and 18 miles per hour at the Government Building about the same time.

The tornado.—The tornado occurred in the eastern portion of the city some time between 7:20 p. m. and 7:30 p. m., local time. Three of the large feed circuits of the Electric Light Co. went out at 7:28 p. m., which was probably the time the tornado was most destructive. When the path of the tornado is traced backward, it passes midway between the two Weather Bureau stations, which are 4 miles apart, and over a thickly settled portion of the city. The instrumental records do not show that any storm of this nature passed between the stations. All the available evidence seems to indicate that the tornado developed close to or over the region where the first destruction of property occurred.

A possible explanation of the origin of the tornado is that the wind at the observatory was blowing at the rate of 24 miles an hour from the *northwest* from 7:08 p. m. to 7:13 p. m. and at the rate of 18 miles per hour from the *southwest* during the same time at the Government Building. (See fig. 2.) Blowing at these rates and directions, the two winds would meet about 10 minutes later at the point where the tornado is supposed to have orig-

inated. These directions and velocities were maintained for only five minutes, after which the directions became west at both stations and the velocities gradually decreased. The assumption that the tornado developed during the time from 7:18 p. m. to 7:23 p. m. and then moved eastward at the rate of about 20 miles an hour seems to agree with available data and records at the time the storm occurred. The topography of the region is favorable for an acceleration of the winds reaching the point in question, as valleys lead up from the south and from the north to the ridge where the first destruction occurred.

The barograms reproduced in figure 2 show that there was no large rapid fall and rise in pressure at the Abbe Observatory and at the Government Building during the progress of this storm. The pressure changes partook rather of the nature of squall-hooks. The lower portion of figure 2 presents in detail the changes in wind direction and velocity at the same two stations from 6:50 to 7:20 p. m. It is regretable that no record of the storm was secured at the Cincinnati Observatory, which stood close to its track.

The tornado passed through the eastern suburb of Cincinnati known as South Hyde Park, or Mount Lookout. The first evidence of the storm was at the corner of Fairfax and Cinnamon Streets, where a small residence was blown down. Two short blocks farther east, on Lavinia Street, a tree was blown over and another small building was partly destroyed. Another short block to the east the storm crossed Madison Road, where the poles carrying the electric cables of the Cincinnati Traction Co. were blown down and several large signboards on the east side of the street were demolished. The traction company states that the current went off on Madison Road at 7:15 p. m., but this may have been due to the thunderstorm, which apparently preceded the tornado somewhat.

After crossing Madison Road the storm passed up a gradual slope and across the Cincinnati golf grounds for a distance of about 1 mile without causing much damage. Passing down the hill to the east of the golf grounds, the storm apparently increased in intensity, and the path of greatest destruction began at the head of Morton Street, about halfway down the hill, where one house was entirely demolished and another partly destroyed. The north half of the roof of the house on the left of the path of the storm was carried 300 feet to the north-northwest over a row of houses and deposited in a yard, while a portion of the roof of the house on the right side of the path was carried about 500 feet across a gully to the south-southeast and smashed to pieces on the side of the hill. These roofs must have been picked up and carried by the gyratory winds until they reached the points where found. The path of destruction was about 50 feet wide on Morton Street.

The path of the storm from the head of Morton Street (points 1 and 2 on map) was plainly marked, passing a little east of north down the hill to the "Arcadia" subdivision, and then up the hill across Linwood Avenue (4 on map), along the south side of the Kessing homestead, popularly known as "Policy Bill Smith's home," and to the corner of Grace and Griest Avenues (6 on map). Trees on the south side of the path lay to the north and northeast, and those on the north side lay to the south and southeast, as indicated by the arrows on figure 1. Along the path of the storm there were many evidences of the gyratory motion of the winds. On the extensive lawn of the Kessing home (5 on map) many large trees were blown down, and they lay in every direction. At one place near the southeast corner of the house four large trees were piled one on top of the other with the trunks radiating like spokes in a wheel. The first tree lay to the north, the next to the northeast, the third to the east across the first two, and the fourth tree lay to the south across the other three. Other topheavy evergreen trees near this point were blown down with the first gust of wind and lay to the west. Nearly all buildings, trees, etc., directly in the path of the storm between Morton Street and Grace Avenue were

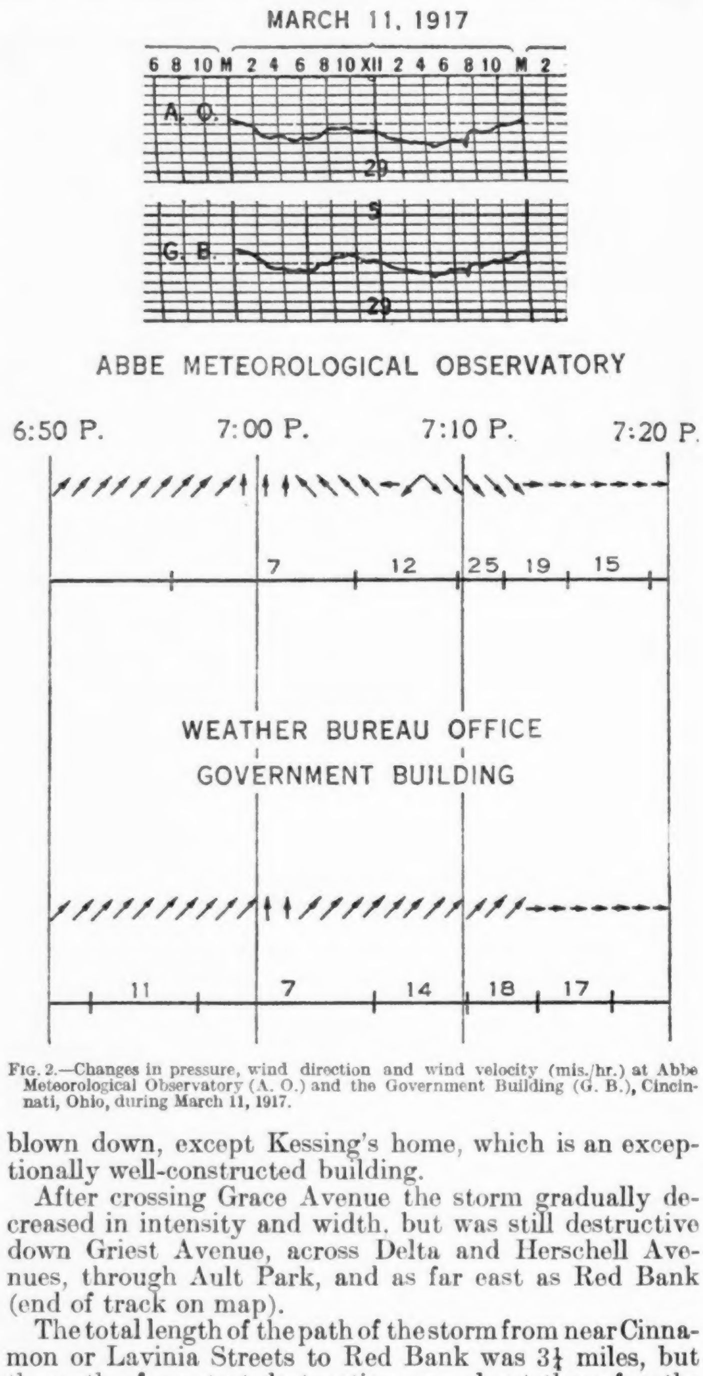

FIG. 2.—Changes in pressure, wind direction and wind velocity (mis./hr.) at Abbe Meteorological Observatory (A. O.) and the Government Building (G. B.), Cincinnati, Ohio, during March 11, 1917.

blown down, except Kessing's home, which is an exceptionally well-constructed building.

After crossing Grace Avenue the storm gradually decreased in intensity and width, but was still destructive down Griest Avenue, across Delta and Herschell Avenues, through Ault Park, and as far east as Red Bank (end of track on map).

The total length of the path of the storm from near Cinnamon or Lavinia Streets to Red Bank was 3¼ miles, but the path of greatest destruction was about three-fourths of a mile, from Morton Street to Delta Avenue, and the width in this region varied between 50 feet and 300 feet or more.

As the storm occurred after dark it was difficult to observe the clouds. A few people, however, claim to have seen the tornado cloud, one witness describing it as pear-shaped with the stem toward the ground, the

center of the cloud having a dull reddish glow. This same witness also describes the lightning as being of the sheet type and of a diffused glare. There is general agreement as to the tremendous hissing, roaring noise accompanying the passage of the tornado. The rainfall attending the storm was light.

As a result of the storm 3 people were killed and 32 injured. Ninety houses were totally or partly wrecked, and the property damage is estimated as between $250,000 and $300,000.

TORNADOES OF MARCH 11, 1917, IN MONTGOMERY COUNTY OHIO.

By R. FRANK YOUNG, Meteorologist.

[Dated: Weather Bureau Office, Dayton, Ohio.]

[It is interesting to note that the two tornadoes here reported came on the same afternoon and but little earlier than the storm reported at Cincinnati which is 0° 15′ west and 0° 40′ south of Dayton.—C. A., jr.]

Two tornadoes passed over western Montgomery County, Ohio, March 11, 1917, about one hour later in the afternoon than the storm that partly destroyed New Castle, Ind. They moved along parallel paths about 4 miles apart, one just south of the towns of Brookville and Trotwood, and the other about the same distance south of Johnsville and New Lebanon. They occurred about 4:30 p. m. and 5 p. m. (local standard time?) respectively.

First storm.—The first of these (I in fig. 1) was apparently a storm of scarcely less violence than the one that visited New Castle, and caused less destruction only because its path lay across a rural community instead of a city.

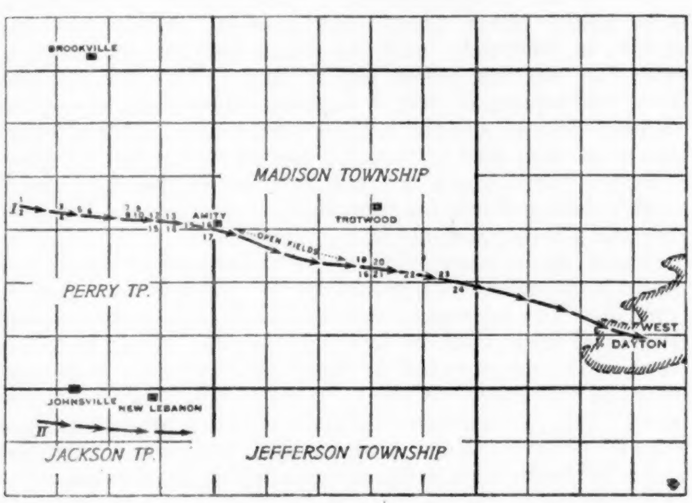

FIG. 1.—Plat of tracks of tornadoes in Montgomery County, Ohio, March 11, 1917.

The track covers a distance of about 9 miles, beginning about the center of section 16 in Perry Township and running a little south of east to the southwest corner of section 23 in Madison Township. Along this line to a width of 150 to 200 yards every farm building, except some of the more substantially built dwellings, was completely destroyed and the débris scattered over the adjacent fields. In some cases débris was caught up in the vortex of the whirl and carried miles along the path.

The storm was of the true tornado type. Of this there is abundant evidence in every part of its track, in the distribution of the débris as well as in its destructive character. The funnel-shaped cloud was observed by nearly every one interviewed, and was seen by many who were 5 or 6 miles away. It was described by some as resembling a gigantic balloon swaying in the wind.

The appearance of the cloud was generally described as of a gray or ashen color with a distinct reddish glow. This apparently more noticeable at distances of 3 to 6 miles.

Very little if any precipitation accompanied the tornado, but there was a heavy downpour of rain immediately after. Coincident with this rain a severe hail storm occurred about 3 to 4 miles north of the path.

The noise attracted the attention of some who were in the track about 10 minutes before its force was felt, while others had not more than a minute's warning. The sound was variously described as, like that of freight trians moving over a trestle, the rumbling of near-by thunder, "a thousand airplanes," etc.

Numerous freak occurrences were related as evidence of the force and character of the storm. In one instance the roof of a brick house was blown off, the walls left intact, and all furniture lifted out and carried away. At another place a coal shed built against the west bank of a deep ravine was carried away. Large pieces of slate from roofs were carried several miles. Pieces of shingle and even straws were found driven into the bark of trees. A piece of tin from a roof was driven about 1½ inches into the trunk of an oak tree.

Half a mile west of the village of Amity stood a thickly wooded plot of about 10 acres across which the storm passed. Here the path along which the axis of the vortex moved was plainly marked. The zone of destruction is about 200 yards in width. A strip about 50 feet wide in the middle of this zone is a tangled mass of trees and brush. On the north side for about 100 feet all uprooted or broken trees fell toward the south and for an equal distance on the south side they point toward the north, the tops of the nearest ones meeting across the middle line.

After leaving this timber the path crosses the east and west road. On the south side of the road, some 50 yards out in the field stood a large walnut tree which was uprooted and fell nearly due north. A short distance farther east on the opposite side of the road was a five-room house. This house with its brick chimney was lifted bodily from its foundation and carried south across the road a distance of 100 feet. It was then completely demolished and a section of the floor was found half a mile east in a field.

The first place destroyed was that of Mary E. Myers (1 in figure) about 15 miles west and 2 miles north of the center of Dayton. As nearly as can be estimated this distance was covered in about 20 to 25 minutes. After leaving the place of Ira Denlinger (24 in the figure) about 5 miles west of Dayton, the vortex rose above the earth but descended again and did considerable damage in West Dayton shortly before 5 p. m.

The only life lost in the storm was that of Jacob Myers, who was fatally injured while clinging to a post to avoid being carried away by the wind. A few persons were injured but none seriously.

The numbers along the route of the tornado as shown on the accompanying map (fig. 1) indicate the locations

of the homes of the following persons, whose buildings were destroyed or badly damaged:

1. Mary E. Myers.
2. Joun Warvel.
3. Jake Myers.
4. Chas. Wampler.
5. John Steck.
6. — Stoner.
7. John Bowser.
8. Ezra Landis.
9. Jacob Keener.
10. Geo. Milliken.
11. Joseph Harry.
12. Ora Keener.
13. Schoolhouse.
14. — Bloom.
15. E. Esterline.
16. A. J. Shafer.
17. H. Troutman.
18. Ed. Kimmel.
19. George Filbrum.
20. G. Conover.
21. J. Roop.
22. Philip Derringer.
23. John Ater.
24. Ira Denlinger.

Second storm.—The storm that passed near Johnsville and New Lebanon (II, fig. 1) was less destructive and its path was only about 3 miles long. The funnel-shaped cloud was observed here also, and there is much other evidence of whirling motion.

UNUSUAL HAILSTORM AT BALLINGER, TEX.[1]

[From notes of E. M. EUBANK, Cotton Region and River Observer at Ballinger, Tex.]

A terrific thunderstorm, accompanied by heavy rain and hail, occurred in the vicinity of Ballinger from 1 to 2:30 a. m., March 16, 1917. It came from the northwest and after passing a short distance west of the observer appeared to split, one part moving to the south and the other to the southeast. About 3 miles south of Ballinger the rainfall was torrential and the hail terrific, with constant electrical display. The water came off the hills in floods and converted small streams into raging torrents, washing away fences and piling the hail in drifts along fences and in places where débris had found lodgment. One such drift of [water borne] hail covered about 2 acres of ground to a depth of 3 feet. On March 20 the hail was still 1 foot deep in drifts, and the last of the hail did not disappear until March 23, the seventh day after the storm. The total amount of precipitation at Ballinger was 1.10 inches, but the drifts must have been of extraordinary depths to persist so long in face of such temperatures and character of the day as are given in the following table for the period that hail remained on the ground.

Date.	Maximum temperature.	Minimum temperature.	Character of day.
1917.	°F.	°F.	
Mar. 16	72	45	Clear.
17	77	32	Do.
18	72	30	Do.
19	78	39	Partly cloudy.
20	88	47	Do.
21	85	49	Clear.
22	89	52	Partly cloudy.
23	82	46	Do.

[1] Communicated by B. Bunnemeyer, meteorologist, Houston, Tex.

The storm caused but little damage only because there were no crops in the ground.

SEVERE LOCAL STORM AT SAN DIEGO, CAL., FEBRUARY, 1917.

A storm of considerable energy, resembling a small tornado in many ways, visited a limited area in the northern part of San Diego at 8:20 a. m., February 17, 1917. While the storm in itself was not of unusual severity, it is the first storm of similar characteristics having occurred in that section of which there is a record, the vicinity being almost free from destructive winds of any nature. The storm was accompanied by heavy rain and hail and moved from southwest to northeast; its path but a few feet in width and about one-half mile in length, with points of destruction centered at four places separated from each other by 500 to 2,000 feet. The damage consisted in a number of roofs being blown off or wrecked. No one was injured.

WINTER OF 1916-17 AT GREENWICH, ENGLAND.

[*Reprinted from* Nature, London, Mar. 22, 1917, 99: 71.]

A good representation of the weather for London is obtained from the Greenwich meteorological observations, and these also show generally the weather conditions over England. The long series of observations affords a trustworthy comparison with past years. Observations for the past winter, December to February, are taken from the results published in the daily weather reports of the Meteorological Office.

The mean temperature for each of the three months was below the average, the greatest deficiency being 4.6°F. in February, and the mean for the whole winter was 3.4 degrees below the normal. The mean winter temperature, 35.9°, was 7 degrees colder than the winter of 1915–16 and was the coldest winter since 1894–95, when the mean was 35.1°, while the lowest in the last 75 years was 34.3° in 1890–91. Frost occurred in the shade on 52 nights during the three months, the occurrences being 18, 19, and 15, respectively [i. e., minima of].

Frost also occurred during the latter half of November, and it is occurring occasionally during the present month. The aggregate rainfall was less than the normal; the total measurement was 4.49 inches, which is 86 per cent of the average fall for the last 60 years. December was the only month with an excess of rain, and in all there were 48 days with rain. The duration of bright sunshine was 63 per cent of the average, and there were 48 sunless days in the three months comprising 90 days in all.

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR MARCH, 1917.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated: Apr. 12, 1917.]

RAL PRESSURE DISTRIBUTION OVER THE NORTHERN HEMISPHERE, EXCEPT EUROPE AND INTERIOR ASIA.

During the first three weeks of the month low pressure, usually of a marked character, prevailed over the western portion of the North Pacific Ocean, depressions having been exceptionally pronounced between the 8th and 10th, and between the 16th and 18th. Over the eastern portion of the North Pacific Ocean, as indicated by the reports from the Aleutian Islands and Alaska, pressures were generally low during the first week of the month, with the greatest fall on the 3d and 4th. From about the 9th to the 19th, inclusive, high pressures prevailed over this area, followed by generally low pressure, except over the Aleutians, where there were several alternations of high and low pressure, each of about two days' duration. The Alaskan depression of the 23d was especially marked, Valdez reporting a barometer reading of 28.62 inches, and Juneau one of 28.68 inches.

The distribution over Alaska was reflected in a lesser degree to the southward and southeastward over the Pacific States and the Northwest, including Canada, and thence eastward to the Atlantic coast.

Over the Middle and South Atlantic Ocean, as indicated by the reports from Bermuda and Turks Island, the pressure was generally high, although not to any pronounced degree, and there were only a few days with pressure below the average. Over the United States proper the LOWS of the month were almost exclusively of the Alberta and Colorado types, and with but two exceptions all passed over the Lakes Region and the districts to the eastward. A single disturbance of the Colorado type moved almost due eastward, passing off the Virginia coast without any unusual development; while another that developed near the mouth of the Rio Grande moved directly northeastward with steadily increasing intensity, finally disappearing in the Atlantic Ocean to the east of Nova Scotia.

STORM WARNINGS.

The evening map of March 3 found the Rio Grande disturbance above mentioned near the mouth of the Mississippi River with a northeastward movement, and as pressure was increasing rapidly to the northwest and northward, northwest storm warnings on the Gulf coast from Pass Christian to Carrabelle were ordered at 10 p. m. By the morning of March 4 the disturbance had moved to northern Georgia, and southwest warnings from Jacksonville, Fla., to Hatteras, N. C., were ordered at 11:30 a. m., with instructions to change to northwest at sunset. At the same time northeast warnings were ordered on the Atlantic coast from Washington, N. C., to New York City. On the evening of March 4 the storm was central over extreme western North Carolina, with quite high pressures to northeastward, and northeast warnings were therefore ordered on the middle Gulf and south Atlantic coasts as far south as Jacksonville. On the morning of the 5th the storm was central over New Jersey, with a further increase in intensity, and moderate northeast gales were in progress on the New England coast. During the day west and northwest gales also occurred along the middle Atlantic coast. At 11:30 a. m. the northeast warnings displayed from Washington, N. C., to New York were changed to northwest, and at 10 p. m., when the storm was central off the southern New England coast, the warnings on the New England coast were changed from northeast to northwest, and gales continued until after the morning observation of March 6, with velocities ranging from 40 to 60 miles an hour.

While this storm was passing over the eastern portion of the country, another disturbance from the northern Pacific coast had moved southeastward and eastward and was central over eastern Nebraska. Accordingly, advisory warnings for strong southeast and south winds were sent to open ports on Lake Michigan; on the following day strong winds occurred as forecast.

By the evening of the 7th this second storm was central over northeastern Wisconsin, with marked high pressure to the southeastward, and at 10 p. m. southwest warnings were ordered on the Atlantic coast from Delaware Breakwater to Eastport, Me. However, this storm did not maintain its original intensity; a moderate secondary disturbance developed over Virginia during the night of the 7th, and the storm warning failed of verification, only fresh winds having occurred.

By the night of March 10 another western disturbance was central over Iowa, with a high pressure area of considerable magnitude over the Atlantic States, and at 10 p. m. southwest storm warnings were ordered on the Atlantic coast from Hatteras to Portland, Me. This disturbance also failed to maintain its intensity after leaving Iowa, so that while moderately strong winds occurred locally along the Atlantic coast, there were none of consequence. By the night of the 10th, owing to the presence of a disturbance central over southeastern New Mexico, southeast storm warnings were ordered on the Gulf coast from Pass Christian to Carrabelle, but as this disturbance failed to develop further, no strong winds occurred. On the night of the 12th marked high pressure prevailed over Lake Superior, with an increasing disturbance over western Texas. Accordingly, advisory warnings of strong northeast winds with snow were sent to open ports on Lake Michigan. This warning was fully justified, both as to wind and weather. On the morning of the 14th the last-mentioned storm was central over upper Michigan, with greatly increased intensity, and southeast storm warnings—to be changed to southwest at sunset—were ordered at noon along the Atlantic coast from Norfolk, Va., to Eastport, Me. Moderately strong winds followed along the New England coast, but there were none of consequence to the southward, and at 10 a. m. of the 15th the warnings were lowered.

The Colorado disturbances continued their rapid sequence, and on the evening of the 15th another was central in pronounced form over western Kansas, and advisory warnings for strong northeast winds, with snow, were again sent to open ports on Lake Michigan and were again verified by the occurrences of the following day.

By the morning of the 17th this storm was central over extreme eastern Lake Superior, with greatly increased intensity and with an eastward movement, and accordingly southwest storm warnings were ordered at 10:30 a. m. along the Atlantic coast from Norfolk to Eastport. These warnings were fully verified, New York reporting a velocity of 56 miles an hour from the southwest. On the morning of the 18th, with the storm central over the Province of Ontario, the southwest warnings were changed to northwest from Delaware Breakwater to Eastport and the high winds continued throughout the 19th, with a maximum velocity of 72 miles an hour at New York and 52 miles an hour at Portland, Me.

On the morning of the 19th an Alberta disturbance was central over Manitoba, with marked high pressure over the Ohio Valley and south, and at 2 p. m. advisory warnings for strong southerly winds were sent to open ports on Lake Michigan. This disturbance did not develop materially and no winds of consequence occurred. The next western storm reached northwestern Missouri on the night of the 22d, with increasing intensity, and again advisory messages of strong winds with rain or snow were sent to open ports on Lake Michigan, and winds occurred as forecast, accompanied by rain. This storm moved rapidly eastward after reaching the upper Lakes region, and on the morning of the 23d southwest storm warnings were ordered on the Atlantic coast from Norfolk to Eastport. During the next 24 hours strong winds and moderate gales occurred as forecast, and on the morning of the 24th, when the storm was central over the lower St. Lawrence Valley the warnings on the Maine coast were changed to northwest and allowed to expire to the southward. By the night of the 24th the winds had diminished and the warnings on the Maine coast were lowered. The next western storm reached Georgian Bay by the morning of the 27th, and at 10:30 a. m. storm warnings were ordered on the Atlantic coast from Wilmington, N. C., to Eastport, Me., with instructions to change to northwest at sunset. These warnings were fully verified by subsequent occurrences, Portland, Me., reporting a maximum velocity of 68 miles an hour from the southeast during the night of March 27-28.

By the night of the 28th an Alberta disturbance was central some distance south of James Bay, with a rapid eastward movement, and southwest storm warnings were again ordered from Delaware Breakwater to Eastport. This disturbance continued to increase in intensity as it moved eastward, and gales occurred as forecast. On the night of the 30th the last disturbance of the month was central over eastern Nebraska. This disturbance was apparently of a decided character, and advisory warnings were sent to open ports on Lake Michigan for increasing south winds, to become strong and shifting to colder northwest. Moderately strong winds occurred, but none of much consequence.

Small-craft warnings were ordered at various times during the month along the middle Gulf and south Atlantic coasts for moderately strong winds that occurred.

COLD WAVES AND FROSTS.

On the evening of March 2 an extensive high pressure area, accompanied by quite low temperature, was central over the extreme Northwest and warnings of a moderate cold wave were accordingly issued for upper Michigan. By the evening of the 3d there was a marked fall over this section and on the morning of the 4th there was a decided cold wave with temperatures ranging from 4° to 14° below zero, and there was also a moderate cold wave over northern and western lower Michigan. At this time the Rio Grande disturbance previously mentioned was central near the mouth of the Mississippi River with the cold high area to the north of still further increased magnitude and intensity. On the following morning warnings were issued for cold waves to occur during the next 36 hours over the Carolinas, Georgia, Alabama, Mississippi, northwest Florida, Tennessee, and portions of Ohio and Indiana. These warnings were fully verified on the morning of the 5th, except over western Tennessee, Indiana, and Ohio, where the fall in temperature was not sufficient to justify a cold-wave warning. On the morning of the 5th warnings of temperature below freezing were issued for the Carolinas, Alabama, northern Florida, and interior Mississippi; also heavy frost warnings for central Florida, and light frosts in southern Florida as far south as the 27th parallel, and on the morning of the 6th heavy frosts occurred as far south as Eustis, Fla., and light frosts as far south as Tampa.

On the morning of the 8th with a cold high pressure area over the west Gulf States, warnings of light frosts were issued for the northern and central portions of Alabama and Mississippi, and frosts occurred as forecast on the following morning, extending into the interior of Georgia. Frost warnings were then repeated for the interior of South Carolina and for the central and northeastern portions of Georgia, and heavy frosts occurred on the morning of the 10th over the Atlantic district.

On the morning of the 14th, with a moderate secondary depression over eastern Tennessee and a moderate high pressure area over Arkansas, warnings of light frost were issued for Mississippi, interior Alabama, and central and northwest Georgia, and these warnings were generally verified by the occurrences on the following morning, except in Mississippi, where the weather became cloudy. On the morning of the 15th light frosts were forecast for the following morning for the interior of the Carolinas, but the rapid approach of one of the western disturbances brought on cloudy weather and a consequent rise in temperature. On the morning of the 17th, by which time the western disturbance had passed northeast of Lake Superior, and a cold high area had reached northern Texas, frost warnings were again issued for the East Gulf States, Georgia, the Carolinas, and eastern Tennessee. On the morning of the 19th heavy and killing frosts occurred over the entire district for which the frost warnings had been issued and warnings were again issued for heavy frosts in the Carolinas and central and northeastern Georgia, and for freezing temperature in Virginia. These warnings failed on account of a rapid change to cloudy weather due to another western disturbance.

On the morning of March 24 pressure was moderately high over the West Gulf States and low to the eastward and warnings for light frosts were issued quite generally for Tennessee, and the East Gulf and South Atlantic States, except Florida, and on the morning of the 20th frosts were reported from the East Gulf States, Tennessee, and southern Virginia, but none in the Carolinas and Georgia. On the morning of the 27th the same general conditions prevailed as on the 24th but with a more decided high area over Texas, and warnings of light frost were again issued for the East Gulf and South Atlantic States, and of heavy frost for Tennessee. These warnings were fully verified by the occurrences on the morning of the 28th, at which time frost warnings were repeated for Virginia, the Carolinas, eastern Tennessee, and interior Georgia. These warnings were partially verified as to Georgia and the Carolinas.

WARNINGS FROM OTHER DISTRICTS.

Chicago district.—As the month of March is between the cold wave and frost warning seasons, special warnings during that month are seldom issued in the Chicago district, and March, 1917, was no exception to this rule. However, a few warnings were issued on the 2d and 3d for Illinois, Missouri, Wisconsin, Minnesota, and Iowa, in advance of a cold wave which pushed down from Alberta. This was the most general warning of the entire month, and thereafter no severe temperatures were observed in the district, except over a small area in the Northwest on the 18th. In the third decade of the month the temperatures were above the normal as a rule, and they reached such a high point in Kansas by the 25th that frost warnings were deemed necessary, and advices were issued to that State on the 26th for a severe freeze. The fall there was quite marked, the temperature falling far below the freezing point.

No warnings of any other character were issued during the month.—*H. J. Cox, District Forecaster.*

New Orleans district.—On the 4th an area of high pressure was moving southeastward over the upper Mississippi Valley and the Plains States and a steep barometric gradient extended to an area of moderately low barometer over the East Gulf States. Northwest storm warnings for the Texas coast and small craft warnings for the Louisiana coast were issued and were verified.

Southeast storm warnings were ordered for the Texas coast at 2:40 p. m. on the 10th, as a midday special observation from Corpus Christi, Tex., indicated that a depression over the southern Rocky Mountain slope was apparently increasing in intensity. The wind did not reach verifying velocity on the east coast, but at Corpus Christi a velocity of 48 miles was recorded. With the low area central over eastern New Mexico on the p. m. map of the 11th, and threatening conditions obtaining along the west coast of Texas, southeast storm warnings were again issued for the Texas coast. Slightly less than the verifying velocity was recorded at Corpus Christi during the ensuing 24 hours, but there were no gales on the east coast.

On the evening of the 26th an area of high pressure was central over the middle Rocky Mountain region and a steep barometric gradient extended into Texas. Northwest storm warnings were ordered for the Galveston section and were verified.

Small-craft warnings were issued for the Texas coast on the 1st, 6th, and 23d, and strong winds occurred as forecast, except on the 1st, in which case the weakening of an area of high pressure, which moved eastward over the Plains States, prevented the wind from increasing on the Texas coast.

The area of high pressure that was over the northern portion of the country on the 1st advanced slowly southeastward, with intensity increasing until after the 4th, and passed to the East Gulf States by the afternoon of the 5th. On account of the gradual lowering of the temperature no cold-wave warnings were issued and no cold waves occurred except in southeastern Louisiana, where the temperature remained high until the 4th. Warning of freezing in the interior of eastern Texas was issued on the 1st, but the movement of the cold area was slower than expected and freezing temperatures occurred only in part of the northwestern portion of east Texas. The retarding effect was due mainly to the continued presence and slight development of a depression over New Mexico. On the 3d the low-pressure area over New Mexico was filling up, and a warning of freezing in northern Louisiana and the interior of eastern Texas, issued on this date, was fully verified.

On the 4th warnings of a hard freeze in the interior of Louisiana and Texas and freezing to the coast were issued and were verified.

Frost warnings for Louisiana were issued on the 5th; for Arkansas, northern Louisiana, and the interior of Texas, on the 7th; for Arkansas and the interior of Louisiana and east Texas, on the 8th; for the western and north-central portions of east Texas, on the 13th; for Arkansas, northern Louisiana, and the extreme northern portion of eastern Texas, on the 14th; for Arkansas and the interior of Louisiana and Texas, with freezing in northwestern Arkansas and below freezing in Oklahoma and the northern portion of western Texas, on the 17th; for Arkansas and the interior of Louisiana, on the 18th; for Arkansas, northwestern Louisiana, and the interior of Texas, with freezing in Oklahoma and the northern portion of west Texas, on the 23d; for northwestern Arkansas and the interior of east Texas, with freezing in western Oklahoma and the northern portion of west Texas, on the 26th; for the interior of Louisiana and east Texas, on the 27th. Freezing temperature was forecast for Oklahoma, northwestern Arkansas, and the northern portion of west Texas, on the 16th. The foregoing warnings of frost and freezing temperature were verified except the frost warning of the 14th, which failed, because of rising temperature due to the development of a depression that moved from Utah to northern New Mexico, and the frost warning of the 18th, which was mostly unverified because of cloudiness in Arkansas and western Louisiana, not foreseen when the forecast was made. In the latter instance temperatures were around 40°. The frost forecast of the 8th was partially verified. Temperatures in western Oklahoma and the Texas Panhandle were generally slightly above freezing on April 1, following the warning of freezing temperature issued on March 31.

Fire-weather warnings for the forested areas of Arkansas were issued on the 6th, 10th, and 15th, and for Arkansas and Oklahoma on the 19th and 30th. Wind velocities and weather generally occurred as forecast in these warnings.—*R. A. Dyke, Assistant Forecaster.*

Denver district.—The weather conditions during March in the Denver district were more unsettled than usual. Active low-pressure areas were central somewhere in the district during two-thirds of the month. In the main the tracks of these disturbances were farther south than usual, and under the influence of the higher pressures that followed there was a persistence of unusually cold weather in the extreme southern part of the district. Frosts were common in central Arizona and freezing temperatures in southeastern Arizona and southern New Mexico. On the morning of the 10th a low-pressure area was central in southeastern Colorado with loops of the depression extending southwestward to northern Arizona. A cold-wave warning was issued for northeastern Arizona. The primary LOW moved eastward, leaving a portion west of the Rocky Mountains which later developed into an important disturbance. The expected cold in northeastern Arizona did not occur until 12 hours after the period covered by the warning. Under the influence of a depression on the eastern Rocky Mountain slope very high temperatures prevailed on the morning of the 30th in northern Colorado and Wyoming. Warnings of a moderate cold wave were issued for northern Colorado in the forenoon and much colder for

Colorado in the afternoon. The warnings were verified by temperature falls of 22 to 44 degrees in northern and eastern Colorado. On the morning of the 31st a low-pressure area was central in northwestern New Mexico with high pressure on the middle Pacific coast. Warnings of a cold wave in central and northeastern Arizona were issued. Sharp temperature falls occurred but they lacked 2 degrees of the required amounts, and in central Arizona the required minimum was not reached by 2 degrees. The warnings of frost in central Arizona, of which there were 17, were fully verified as a rule.—*Fred. H. Brandenburg, District Forecaster.*

San Francisco district.—The storms moved eastward well to the north and gave precipitation only in the northern portion of the district, except that of the 8th, which moved rapidly southeastward along the eastern slope of the Sierra Nevada and gave rain to the entire district. Rain was forecast only for the north section.

Frosts occurred frequently in all sections, but owing to the backwardness of the season, the damage was slight in most places.

Storm warnings were issued on the 8th, along the north coast and on the 10th, along the south coast, and in both instances were justified.—*G. H. Willson, District Forecaster.*

Portland, Oreg., district.—In this district March, 1917, was rather more stormy than usual, and in general there was a slight excess in the amount of precipitation in western Oregon, also in western Washington except at Seattle where there was a deficiency. East of the Cascade Mountains less than the normal amount of precipitation occurred, due to the controlling influence of the high pressure areas, most of which moved eastward or northeastward from the Oregon-California coast. Our weather conditions were dominated by high pressure areas during the first three days of the month, on the 5th and 6th, from the 14th to the 18th, inclusive, and again on the 25th. On the 4th, from the 7th to the 13th, the 19th to the 24th, and the 26th to the 31st, low pressure areas were the dominating factors; those during the second and fourth periods mentioned were forced farther south than usual by areas of high pressure over northwestern and central Canada.

Storm warnings were issued on 12 dates; 10 were general warnings and 2 local, and all were verified except those on the 8th and 12th, while one on the 26th was partially verified. Of these warnings, 9 were southwest, 1 northwest and 2 southeast. Subsequent developments proved that storm instead of small-craft warnings ought to have been hoisted at the mouth of the Columbia River on the morning of the 28th; all the other warnings were timely and, excepting the northwest warning on the 8th, necessary.

Small-craft warnings were ordered on 8 days and all were justified.

As has been customary, frost warnings were resumed this month for western Oregon and western Washington. Of the 11 frosts predicted 8 were verified, and 3 were not on account of cloudiness. These warnings were all general for the section mentioned. On account of the lateness of the fruit blossoming season in the Rogue River Valley, definite forecasts of expected minimum temperatures were not asked for until the morning of the 27th. On the 30th a warning of heavy frost sent out in the morning was supplemented by an evening prediction of a minimum temperature of 27°; the acutal minimum recorded was 25°, but so far as known little, if any, damage resulted as buds were not very far advanced.

A cautionary warning of prevailing weather conditions favorable for the occurrence of avalanches in mountainous sections was sent out on the 26th. The snow depth in the mountains is greater than usual according to reliable reports.

Warnings in the interest of the stockmen were sent out generally on five dates. Of these three were for expected unfavorable weather conditions and two were for periods of favorable weather, and all were justified and timely. On account of the unusual depth of the snow in the mountains and on the customary feeding grounds, more than the normal amount of dry feeding has been resorted to; this has resulted in a serious shortage of hay in some localities, and stockmen are very anxious to get any definite information regarding favorable weather if it is expected to continue for several days in order that they may, when practicable, move the stock to available grazing grounds. The feed shortage has resulted in a weakened condition of sheep especially, so that many ewes will probably not survive the lambing season, and the lambs will probably be so weak that many of them will die. Such reports as we have received indicate that these warnings are appreciated by the live stock interests. On March 8, Dan P. Smythe, of Smythe Bros., prominent sheepmen of Arlington stated:

The special forecast furnished by the Weather Bureau is proving of great value to stockmen, particularly to the sheepmen. The service has only been furnished for a year and during that time I have had occasion to observe that the predictions of big storms have been made with wonderful accuracy.

Personally I know that Smythe Bros. have on a number of occasions benefited from them, and we are learning to watch them with serious concern. When a sudden change in the weather is predicted, we always take precautions to protect our stock. The last big storm which broke over eastern Oregon was predicted in time to give the sheepmen time to prepare for it. Those who did, did not suffer.

I have talked with many sheepmen who at first ridiculed the service and find that all have been converted to its value. They are ready to testify to the direct benefits they have derived. I believe that when the system of warning stockmen is developed it will prove as big a boon as are the forecasts to the shipping interests.

On March 14th, Forest Supervisor Homer Ross of Prineville, Oreg., wrote us as follows:

Your telegram to this office on the morning of March 12 was of great value to the stockmen and the public in general in this community. When your telegram arrived about 9 a. m. the sky was clear, the sun shone warm, and it appeared as though our long stormy spell was over. In spite of this, your forecast predicted cold, windy weather with snow that night. This information was telephoned from this office out along the various telephone lines leading into the communities where cattlemen and sheepmen reside, and in addition was posted in the post-office window. That afternoon it turned extremely cold with high wind and snowed considerably during the night.

On March 24th, the vice president of the First National Bank of Jerome, Idaho, wrote us:

The weather forecasts received from your office are very much appreciated by stockmen in this locality. On account o the extraordinary winter weather these forecasts will probably be very helpful for another few weeks. The reports have checked out quite closely with the actual conditions here. On account of being better supplied with feed than most sections, no live stock losses have as yet been experienced even though the weather has been quite severe at times. If the weather should continue severe for another couple of weeks there is a possibility of some losses. It is raining, however, to-day, which you will note is in accordance with your forecast and the stockmen are feeling more hopeful.

—*T. Francis Drake, Local Forecaster.*

COLD WAVES AND FREEZING TEMPERATURES AT TAMPA, FLA.[1]

By WALTER J. BENNETT, Meteorologist.

[Dated: Weather Bureau Office, Tampa, Fla., March, 1917.]

Since April, 1890, when the Weather Bureau office was established in Tampa, there have been recorded only 51 dates when the temperature fell to 32° or below. Of these, 17 were dates immediately following other dates, so there were only 34 cold spells during which the freezing temperature was reached. A study of the weather conditions preceding and attending these occurrences was begun two years ago, at the Tampa office, and only recently completed.

The work involved copying the 8 a. m. weather maps for each date on which freezing temperature occurred, and also the maps for 24 and 48 hours preceding each. An additional study was made of the distribution of low temperatures over Florida on the same dates, by copying on a map of Florida the minima at all points from which data were obtainable, so that they might be compared with the temperature at Tampa.

The typical cold-wave map for this section shows a low-pressure area or storm center moving north-northeastward up the Atlantic coast, and a great area of high pressure moving southeastward over Nebraska, Kansas, Oklahoma, and Texas. This pressure distribution induces a flow of cold air from the northwest. The rapidity of the fall in temperature depends roughly on the intensity of the HIGH and the intensity of the LOW, and on the rate at which they are moving.

Different maps show wide variations from the typical one, but a few general rules have been found to hold approximately. These rules apply only to the first occurrence of freezing temperature at Tampa in a cold wave, and not to a second occurrence immediately following. Broad as these rules are exceptions can be found. Each exception is noted, and description given of actual conditions. In general the exceptions were when the temperature was already low at Tampa 24 hours preceding, or when the freezing temperature was just barely reached.

RULE I. The high-pressure area must be 30.40 inches or over, and the 30.40 isobar must reach as far south as Oklahoma, 24 hours preceding. (4 exceptions.)

Exception 1. January 6, 1893. Barometer above 30.30 inches over Arkansas, below 29.30 off New England. Temperature 47°F. at Tampa, 32° at Mobile, below 0°F. in Missouri. Tampa minimum next morning, 31°.

Exception 2. January 13, 1893. Barometer above 30.30 inches over Texas, below 29.30 over Nova Scotia. Temperature 45° at Tampa, 35° at Mobile, below 0°F. in Missouri. Tampa minimum next morning, 31°.

[1] Weather maps illustrating conditions followed by frost or freezing temperatures in Florida are published in the handbook "Weather Forecasting the United States" (W. B. No. 583), Washington, 1916. See there, figures 111 to 116, inclusive, accompanying the text of pp. 190-191; also text on p. 160.

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Exception 3. January 1, 1900. Barometer above 30.30 inches over Oklahoma, 30.60 over Montana, below 29.60 off New England. Temperature 52° at Tampa. Tampa minimum next morning 32°.

Exception 4. December 18, 1901. Barometer 30.36 inches at Mobile, below 30.00 off Hatteras. Temperature at Tampa 35°, at Mobile 20°, below 0°F. in Missouri. Tampa minimum next morning, 30°.

RULE II. The low-pressure area must be on the Atlantic coast and intensity 30.00 or below, 24 hours preceding. (4 exceptions.)

Exception 1. December 31, 1894. Barometer 30.10 inches on Georgia coast, 30.50 over Texas. Temperature 51° at Tampa, 31° at Mobile, 10° in Missouri. Tampa minimum next morning, 31°.

Exception 2. February 12, 1899. Barometer 30.02 inches at Tampa. Immense high pressure area with barometer 31.00 in central Texas. Temperature 62° at Tampa, 20° at Mobile, below 0° F. in Arkansas. Tampa minimum next morning, 28°.

Exception 3. December 20, 1901. Barometer at Key West 30.18 inches, in Texas 30.80. Temperature 49° at Tampa, 18° at Mobile, below 0°F. in Missouri. Tampa minimum next morning, 24°.

Exception 4. November 27, 1903. Barometer at Hatteras 30.04 inches, at Memphis 30.44. Temperature at Tampa 36°, at Mobile 28°. Tampa minimum next morning, 32°.

RULE III. The 32°F. isotherm must reach the Gulf coast 24 hours preceding. (5 exceptions.)

Exception 1. December 28, 1890. Temperature at Tampa 43°, at Mobile 34°. Barometer above 30.50 inches at Mobile, below 29.40 over Nova Scotia. Tampa minimum next morning, 31°.

Exception 2. January 13, 1893. Temperature at Tampa 45°, at Mobile 35°. Below 0°F. over Missouri. Barometer over Texas above 30.30, over Nova Scotia below 29.30. Tampa minimum next morning, 31°.

Exception 3. March 4, 1893. Temperature 72° at Tampa, 38° at Mobile, below 0°F. in Nebraska. Barometer above 30.70 in Oklahoma, below 29.30 at Hatteras. Tampa minimum next morning, 32°.

Exception 4. February 1, 1898. Temperature 44° at Tampa, 34° at Mobile, below 0°F. in Iowa. Barometer above 30.60 in Oklahoma, below 29.00 off New England coast. Tampa minimum next morning, 31°.

Exception 5. December 29, 1909. Temperature 48° at Tampa, 38° at Mobile, below 0°F. in Missouri. Barometer 30.40 at Oklahoma, 29.66 at Hatteras. Tampa minimum next morning, 27°.

RULE IV. The barometric gradient from Oklahoma, or center of HIGH east or south of Oklahoma; to Hatteras, or center of LOW south of Hatteras, 24 hours preceding, determines the fall in temperature at Tampa as follows:

- Gradient of 0.90 inch or more means fall of 20 degrees or more.
- Gradient of 0.60 or more means fall of 10 degrees or more.
- Gradient of 0.40 or less means fall of less than 10 degrees.

The above rules were formulated before the recent freeze, and were verified by this freeze. The isobar of 30.40 inches passed through Alabama; the barometer at Hatteras was 29.78, temperatures were below 32° F. on the Gulf coast except the Florida Peninsula. The gradient was 1.00 inch from Texas to Hatteras, and the resulting fall in temperature was 18 degrees at Tampa, within 2 degrees of the fall called for by Rule IV.

IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS DURING MARCH, 1917.

By ALFRED J. HENRY, Professor in Charge.

[Dated: Weather Bureau, Apr. 20, 1917.]

The rainfall over the southern Appalachian region in March, 1917, was considerably heavier than elsewhere in the United States (see Chart V, Total Precipitation for March, 1917). The monthly totals exceeded 10 inches at a number of points in the Tennessee and Cumberland watersheds in Tennessee and western North Carolina, also in southeastern Kentucky and southern West Virginia. As a consequence practically all of the streams of these regions were out of their banks for a greater or less time during the month. Likewise the rivers of the Piedmont region of the Carolinas and the rivers of Alabama and Georgia were also in flood.

The greatest flood of the month, however, was that in the Tennessee River due to a continuous period of rains that began on the 1st and ended on the 5th.

The meteorological phenomena that led up to this flood may be found in the development and movement of cyclonic and anticyclonic systems over the Tennessee watershed, beginning February 28 and terminating March 5. On February 28 a weak cyclonic system was centered directly over eastern Tennessee attended by general rains over that State, and adjacent regions to the east and northeast. The movement of an anticyclone eastward from the lower Missouri Valley to the Middle Atlantic seaboard in the 36 hours ending 8 a. m., March 2, 1917, evidently prevented the weak cyclonic system before mentioned from pursuing the normal northeastward movement; consequently, it was held over eastern Tennessee for a much longer time than would ordinarily be the case. Meanwhile, a second cyclonic system or area of low pressure that had remained over southern Texas for 36 hours began to move northeastward. By the morning of the 30th it had reached eastern Tennessee and again within a period of less than 48 hours atmospheric conditions favorable to heavy precipitation over that region were present. The heavy rains of the 3d and 4th (see Table 1) were due to the second disturbance which did not move from its position on the morning of the 3d until the night of the 4th–5th. The rain had practically ceased by the morning of the 5th and the next few days were clear and cold with night temperatures below freezing.

Table 1 below presents the daily precipitation at a number of stations in the Tennessee River basin above Chattanooga.

TABLE 1.—*Daily precipitation, in inches and hundredths, at points in the Tennessee Basin above Chattanooga, Tenn., March, 1917.*

Dates.	Knoxville, Tenn.	Asheville, N. C.	Dandridge, Tenn.	Newport, Tenn.	Greeneville, Tenn.	Rogersville, Tenn.	Mendota, Va.	Bluff City, Tenn.	Elizabethton Tenn.	Loudon, Tenn.	Chattanooga, Tenn.	Speers Ferry, Va.	Clinton, Tenn.	Kingston, Tenn.	McGhee, Tenn.	Tazewell, Tenn.	Charleston, Tenn.	Bryson, N. C.	Murphy, N. C.
1917.																			
Mar. 1	2.22	0.75	1.82	1.80	1.75	1.90	1.05	1.07	1.02	2.39	0.88	1.10	2.12	2.20	1.90	1.38	0.91	1.50	1.94
2	0.17	0.46	0.42	0.89	0.43	0.30	0.61	0.48	0.63	0.25	0.75	0.59	0.20	0.15	0.22	0.30	0.58	0.65	1.01
3	1.71	0.33	1.16	0.98	0.83	1.45	1.30	0.73	0.73	1.79	1.92	1.50	1.96	2.05	1.32	1.95	1.55	0.99	1.61
4	2.04	0.45	1.97	1.75	1.60	1.60	1.75	0.85	1.15	1.77	1.23	1.20	2.15	2.02	1.83	1.97	1.45	2.95	2.00
5	0.38	0.36	0.62	0.60	0.43	0.73	0.56	0.55	0	0.06	0.12	0.24	0.26	0.11	0.26	0.50	0.20	0.55	0.30
6	T.	0	T.	0.06	0.11	T.	0	0.15	T.	0	T.	0	0	0	0	T.	0	0.02	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0.22	0.15	0.53	0.30	0.26	0.24	0.37	0.18	0.10	0.14	0.16	0.10	0.20	0.17	0.35	0.24	0.05	0.50	0.24
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0.17	T.	0.08	0	0.04	0.02	0	0	0	0.19	0.18	0	0.52	0.30	0.20	0	0.06	0.05	0
12	0	0.04	0.13	0.20	0.78	0.52	0	0.50	1.00	0	0.02	0.70	0	0	0	1.50	0	0.70	0
13	1.35	0.56	1.81	1.40	0.30	0.43	0.47	0.80	0.0	0.76	0.26	0.32	1.04	0.55	1.18	0.34	0	0.25	0.14
14	0.49	0.03	0.62	0.40	0.48	0.43	0.15	0.20	0.35	0.76	0.57	0.24	0.58	0.54	0.45	0.37	0.22	0.50	0.34
15	0	0	0	0.10	0.09	T.	0.12	0.20	0	0	0	0.22	0	0	0	0	0	0.06	0.13
16	0.06	0.02	0.06	0.04	0.03	0.07	0	0.05	0	0.18	0.10	0.05	0.12	0.37	0.02	0.25	0.05	0	0.03
17	1.86	0.37	1.38	1.20	0.93	1.46	1.54	1.10	1.10	1.47	1.45	1.52	2.00	1.64	1.41	2.05	1.30	0.14	1.18
18	0	0.04	0	0.04	0.03	T.	0	T.	0	0	T.	0	0	0	0	T.	0	0.97	0
19	0	0.04	0	0	0.01	T.	0	0.04	T.	0	0	0	0	0	0	T.	0	0.06	0
20	T.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04
21	0.72	0.15	0.75	0.32	0.68	0.66	0.16	0.30	0.65	0.65	1.42	0.21	0.73	0.65	0.81	0.62	0.98	0.97	1.40
22	0.01	0.13	0.13	0.58	0.16	0.13	0.28	0.25	0	0.13	0	0.35	0.14	T.	0	T.	0	0.23	0.08
23	0.08	0.03	0.08	0.09	0.10	0.01	0	0	0	0.26	1.04	0	0.09	0.30	0.08	T.	0.40	0.44	0.90
24	1.70	1.02	1.64	1.45	1.26	1.53	1.56	1.35	1.14	1.31	1.37	1.35	1.45	1.33	1.85	1.84	1.20	2.06	2.00
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0.40	0	0	0	0	0	0	0	0	0	0
27	1.01	0.94	0.86	0.90	0.77	0.50	0.41	0.30	0.05	0	2.48	0.32	1.20	1.32	1.32	0.86	1.60	2.50	2.00
28	T.	T.	0.04	0.12	0.12	0.03	0.02	0.05	0	1.07	0	0	0	0	0	T.	0.04	0.02	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**14.19**	**5.87**	**14.08**	**13.13**	**11.19**	**12.01**	**10.35**	**9.15**	**8.32**	**13.18**	**13.95**	**10.01**	**14.76**	**13.70**	**13.19**	**14.17**	**10.59**	**16.12**	**15.34**

TABLE 2.—*Daily stages in the Tennessee and its tributaries during the flood of March, 1917.*

Dates.	Rogersville, Tenn.	Dandridge, Tenn.	Knoxville, Tenn.	Loudon, Tenn.	Guntersville, Ala.	Chattanooga, Tenn.	Florence, Ala.	Johnsonville, Tenn.	Riverton, Ala.	Bridgeport, Ala.	Decatur, Ala.
Flood stages	*14.0*	*10.0*	*12.0*	*25.0*	*31.0*	*33.0*	*18.0*	*31.0*	*32.0*	*24.0*	*21.0*
1917.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Mar. 1	5.3	3.0	5.4	4.8	17.1	17.7	11.7	23.0	26.6	10.7	12.8
2	10.5	9.8	15.0	13.2	18.2	20.9	13.3	22.3	28.1	12.2	14.0
3	11.0	8.3	17.0	16.0	22.5	29.0	16.0	24.5	33.1	17.8	15.7
4	13.0	11.2	19.5	21.0	29.4	35.6	19.9	27.0	37.6	21.6	18.0
5	17.1 [a]	16.0 [b]	28.2 [c]	29.6 [d]	32.5	40.5	21.5	28.9	40.9	25.6	19.5
6	12.0	10.5	24.2	28.0	34.0	44.5	22.1	30.5	42.8	27.8	20.4
7	7.3	7.3	15.9	20.6	35.9	47.3 [f]	22.2	31.9	43.4	29.6	21.0
8	6.0	5.4	10.0	12.6	37.2	47.4	22.6	33.0	43.6	30.7 [h]	21.9
9	5.4	5.0	8.0	9.2	38.5	44.9	22.6	33.7	43.8	30.6	22.4
10	4.8	4.2	7.6	8.5	39.4 [e]	38.0	23.0	34.0	44.2	28.0	23.1
11	4.4	3.6	5.8	6.4	38.7	27.9	24.0	34.3	45.5	25.3	23.6
12	4.3	3.4	5.4	5.7	36.5	20.8	24.7	34.8	46.6	19.7	23.7
13					33.8	17.9	24.3	35.5	47.0	14.0	23.4
14					29.7		23.5	36.2	46.5	12.1	22.2
15					25.2		21.9	37.0	45.5		20.2
16					22.7		19.2	37.7	43.4		18.0
17							17.5	38.4	41.1		16.9
18							17.8	38.8 [g]	40.2		16.5
19							16.8	38.7	39.0		16.4
20							15.7	38.3	37.4		
21								37.4	36.8		
22								36.2			
23								35.5			
24								35.0			

[a] Rogersville, Tenn., 5th, 1 p. m., stage=17.3 feet.
[b] Dandridge, Tenn., 5th, during night of 4th-5th, stage=16.7 feet.
[c] Knoxville, Tenn., 5th, 12:20 p. m., stage=28.6 feet.
[d] Loudon, Tenn., 5th, 3:00 p. m., stage=30.2 feet.
[e] Guntersville, Ala., 10th, 7 to 11 a. m., stage=39.4 feet.
[f] Chattanooga, Tenn., 7th, 8:40 p. m., stage=47.7 feet.
[g] Johnsonville, Tenn., 18th, 6 p. m., stage=38.9 feet.
[h] Bridgeport, Ala., 8th, 2:00 p. m., stage=30.9 feet.

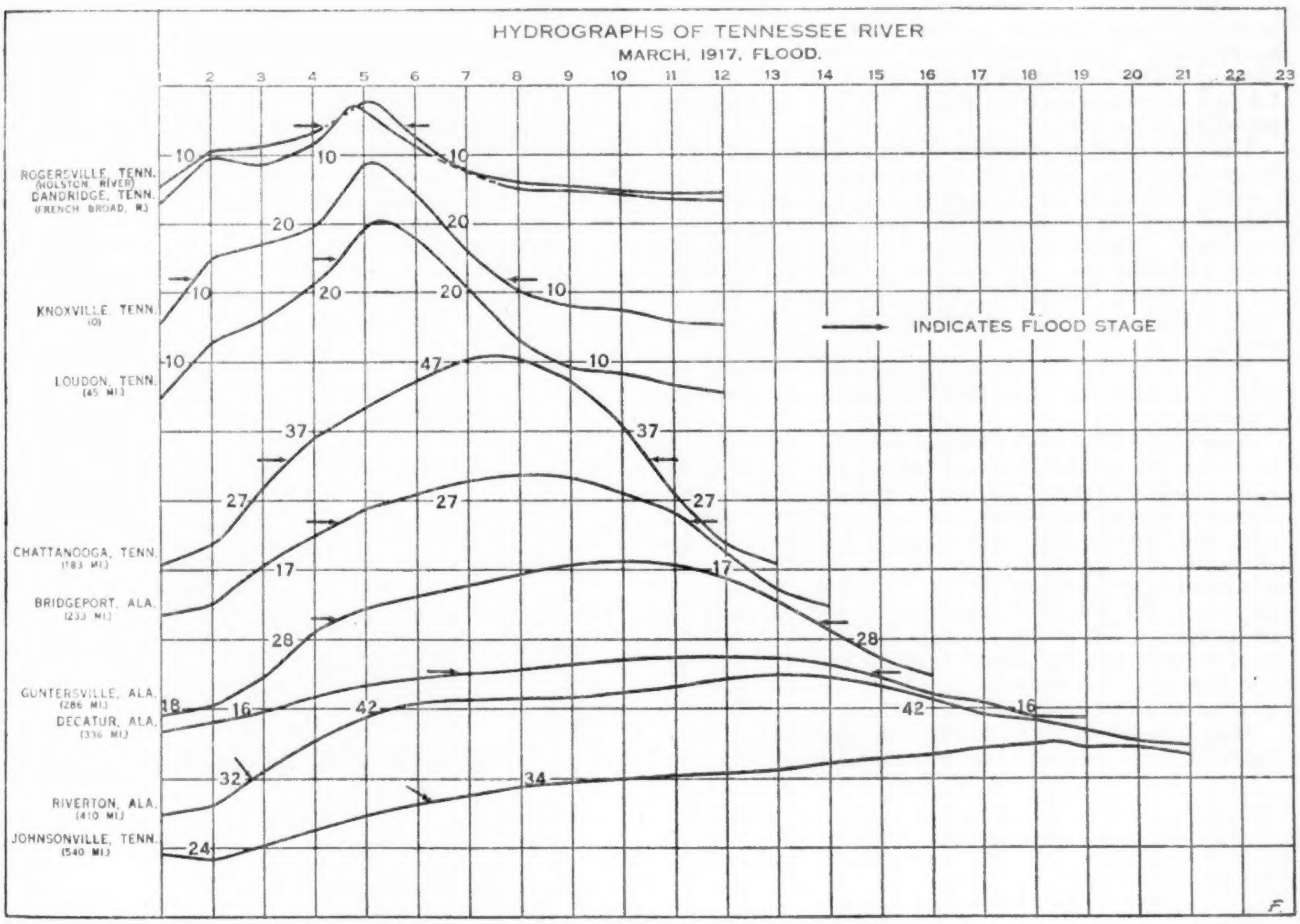

FIG. 1.—Hydrographs for stations on the Tennessee River during the floods of March, 1917. Distances below **Knoxville** are given by the figures in ( ) beneath the station name. (See Table 2.)

The rainfalls in Table 1 clearly show that while the daily amounts were not extraordinary the period of rainy days was practically continuous from the 1st to the 5th of the month. It is also apparent at a glance that this period of rainy days was the direct and immediate cause of the flood in the Tennessee. The areal distribution of the rainfall is fairly uniform except that in the upper French Broad, as at Asheville, N. C., there was decidedly less rain than at other points to the southwest. The French Broad at Asheville barely passed above the flood stage on the 4th and fell below flood stage on the 6th.

Figure 1 includes a hydrograph for the French Broad at Dandridge, Tenn., 46 miles above the mouth of the river. This hydrograph shows that the lower reaches of the stream were in sharp flood and that the flood crest synchronized very well with that of the Holston River, the other of the two main tributaries of the Tennessee. These two tributaries unite at Knoxville, where the flood crested about noon of the 5th. Between Knoxville and Loudon, the next down-river station, two important tributaries join the main stream, viz, the Little River and the Little Tennessee River. Both of these head in the mountains of western North Carolina, where the rainfall of the 4th and 5th was undoubtedly heavy; see the record for Bryson City and Murphy, N. C.

The hydrograph for Loudon shows that the crest of the flood at that point was reached slightly earlier on the 5th than at Knoxville, although the latter is 45 miles farther upstream. There must have been therefore a more prolonged crest at Loudon than is shown by the hydrograph. This is established by the fact that the 24-hour fall at Loudon from the 5th to the 6th was but 1.4 feet as compared with a fall of 4 feet for the same period at Knoxville.

The next down-river station is Chattanooga, 183 miles below Knoxville. Here the character of the flood wave is much altered, as might be expected, being much flatter than at up-river points, and the crest occurring about 2 days later. Below Chattanooga the flood wave is still more flattened out. At Johnsonville, Tenn., 540 miles by river below Knoxville, there was simply a long flat swell, beginning on the 2d and ending about the 18th—see fig. 1.

Numerous other floods occurred in the rivers of the South Atlantic and East Gulf drainage, as shown by Table 4.

A moderate flood swell passed down the Ohio, beginning at Pittsburgh on the 13th and passing Cincinnati on the 17th, at a crest stage of 56.1 or 6.1 feet above flood stage. The crest passed Louisville 1 or 2 days later and Evansville, Ind., on the 22d, at a stage of 42.9 feet, 7.9 feet above flood stage. The crest of this flood passed into the Mississippi at Cairo on the 25th, with the river at 49.2, at which height it remained on a stand until the 29th, when a fall of 0.2 foot was registered. The river then continued to fall slowly until the end of the month, but began to rise again in April and reached a second crest of 50.1 feet on April 4–5, 1917.

Warnings of all these floods were distributed in advance and the property loss was therefore greatly minimized. There was an unpreventable loss of nearly a million dollars, as exhibited in the statement below, the greater part of which was sustained in the city of Chattanooga, Tenn. The loss attributed to "prospective" crops may or may not be fully realized, owing to the early season of the overflow.

Loss by flood, March, 1917.

The loss in many cases was minimized by the fact that no crops were on the ground and that warnings of the approach of the flood waters were distributed sufficiently in advance to permit the withdrawal of movable property from the zone of danger.

Drainage division.	Tangible property; bridges, highways, etc.	Crops.		Live stock, other movable property.	Suspension of business.	Totals.
		Matured.	*Prospective.*			
South Atlantic	$4,000	$100	$5,500	$400	$7,375	$17,375
East Gulf	500	....	30,000	11,000	10,100	51,600
Mississippi:						
Eastern tributaries—Tennessee and Ohio	498,185	....	53,000	2,320	38,500	592,005
Western tributaries—Missouri	100,000	....	....	....	....	100,000
Total	602,685	100	88,500	13,720	55,975	760,980

Saved by warnings, estimated.

South Atlantic	$ 99,700
East Gulf	88,000
Mississippi, eastern tributaries	1,050,500
Total	1,238,200

The details of floods in all parts of the country are presented below in Tables 3, 4, 5, and 6. Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 3.—*Flood stages in rivers of the North Atlantic drainage, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Connecticut	Hartford, Conn	16	26	(*)	18.3	30
Hudson	Troy, N. Y	15	28	28	17.7	28
Do	Albany, N. Y	12	28	28	12.7	28
Mohawk	Utica, N. Y	11	....	....	10.3	25
Do	Schenectady, N. Y	15	25	25	17.9	25
Delaware, E. Br	Fishs Eddy, N. Y	10	28	28	12.3	28
Susquehanna	Bainbridge, N. Y	11	28	29	12.4	28
Do	Binghamton, N. Y	14	....	....	13.9	28
Unadilla	New Berlin, N. Y	8	25	28	10.4	28
Chenango	Sherburne, N. Y	8	24	29	8.9	28
Potomac	Cumberland, Md	8	12	13	12.0	12
Do	Harpers Ferry, W. Va	18	....	....	17.5	13

*Continued above flood stage after the end of the month.

TABLE 4.—*Flood stages in rivers of the South Atlantic and east Gulf drainage, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			Feet.	
James	Buchanan, Va	15	5	5	17.6	5
Do	Columbia, Va	18	5	6	24.7	6
Do	Richmond, Va	10	5	7	14.1	6
Roanoke	Randolph, Va	21	5	7	26.6	6
Do	Weldon, N. C	30	5	9	41.8	8
Dan	Danville, Va	8	......	......	7.8	4
Do	Clarksville, Va	12	7	7	12.4	7
Tar	Tarboro, N. C	18	7	11	21.2	10
Do	Greenville, N. C	13	7	13	15.2	11
Fishing Creek	Enfield, N. C	14	6	7	14.3	7
Neuse	Neuse, N. C	18	......	......	17.6	5
Do	Smithfield, N. C	13	5	11	18.3	7
Do	....do	13	27	(*)	13.6	31
Cape Fear	Elizabethtown, N. C	20	6	10	30.3	8
Do	....do	20	26	29	25.3	27
Do	Fayetteville, N. C	35	6	7	41.3	6
Haw	Moncure, N. C	22	5	5	23.6	5
Pee Dee	Cheraw, S. C	27	5	8	33.3	6
Do	....do	27	26	26	28.8	26
Santee	Rimini, S. C	12	(†)	18	18.7	10
Do	....do	12	24	(*)	17.0	31
Do	Ferguson, S. C	12	(†)	20	14.7	10
Do	....do	12	24	(*)	13.9	31
Catawba	Catawba, S. C	11	5	6	17.5	5
Do	....do	11	25	25	13.5	25
Wateree	Camden, S. C	24	5	7	30.3	6
Do	....do	24	26	26	27.0	26
Congaree	Columbia, S. C	15	6	6	17.8	6
Do	....do	15	......	......	14.8	26
Broad	Blairs, S. C	15	5	6	18.1	6
Do	....do	15	25	25	15.5	25
Saluda	Pelzer, S. C	7	5	6	8.6	5
Do	....do	7	24	27	10.2	25
Do	Chappells, S. C	14	5	8	19.0	6
Do	....do	14	26	29	18.0	27
Broad	Carlton, Ga	11	25	25	12.3	25
Do	....do	11	27	28	13.0	27
Oconee	Milledgeville, Ga	22	5	6	24.6	5
Do	....do	22	28	28	23.2	28
Ocmulgee	Macon, Ga	18	5	6	19.5	5
Do	....do	18	27	29	19.4	28
Do	Abbeville, Ga	11	(†)	2	11.6	1
Do	....do	11	9	14	14.3	11
Do	....do	11	29	(*)	12.9	31
Do	Lumber City, Ga	15	......	......	14.5	14-15
Flint	Woodbury, Ga	10	5	5	10.1	5
Do	Montezuma, Ga	20	......	......	18.4	7
Do	Albany, Ga	20	10	12	20.8	11
Chattahoochee	Norcross, Ga	16	25	25	16.7	25
Do	West Point, Ga	20	......	......	18.4	5
Do	....do	20	......	......	19.6	28
Do	Eufaula, Ala	40	5	7	43.3	6
Do	Alaga, Ala	30	5	9	36.9	7
Do	....do	30	28	(*)	32.5	30
Alabama	Montgomery, Ala	35	5	11	48.3	7
Do	....do	35	27	(*)	40.8	29
Do	Selma, Ala	35	5	14	50.1	9
Do	....do	35	27	(*)	43.5	31
Tallapoosa	Milstead, Ala	40	4	5	45.0	5
Coosa	Rome, Ga	30	5	6	30.5	5
Do	....do	30	28	28	30.0	28
Do	Gadsden, Ala	22	5	13	25.2	9-10
Do	....do	22	25	(*)	25.2	31
Do	Lock No. 4, Ala	17	4	13	20.3	5
Do	....do	17	25	(*)	19.4	27
Do	Wetumpka, Ala	45	5	7	47.8	6
Do	....do	45	......	......	41.5	28
Etowah	Canton, Ga	11	4	5	15.6	4
Do	....do	11	24	25	17.0	24
Oostanaula	Resaca, Ga	25	5	7	30.2	6
Do	....do	25	25	29	28.0	26
Cahaba	Centerville, Ala	25	4	4	26.8	4
Do	....do	25	24	24	25.0	24
Tombigbee	Demopolis, Ala	39	)	20	54.6	12
Do	....do	39	24	(*)	52.7	31
Black Warrior	Tuscaloosa, Ala	46	4	7	54.6	5
Do	....do	46	24	28	54.0	25
Pascagoula	Merrill, Miss	20	6	9	20.5	6
Chickasawhay	Enterprise, Miss	21	6	7	22.5	6
Do	Shubuta, Miss	27	......	......	26.9	9
Pearl	Edinburg, Miss	21	6	8	22.8	7
Do	Jackson, Miss	20	(†)	18	26.6	13
Do	Columbia, Miss	18	4	11	20.8	7

* Continued above flood stage after the end of the month.
† Above flood stage at the beginning of the month.

TABLE 5.—*Flood stages in the Ohio River drainage, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			Feet.	
Ohio	Pittsburgh, Pa	22	13	13	23.1	13
Do	Beaver Dam, Pa	30	13	14	33.0	13
Do	Dam 13, near Wheeling, W. Va.	36	14	14	37.0	14
Do	Marietta, Ohio	33	14	16	36.7	15
Do	Parkersburg, W. Va	36	15	16	38.5	15
Do	Dam 19, W. Va	39	15	15	39.0	15
Do	Point Pleasant, W.Va.	40	14	18	47.3	15
Do	Dam 26, Hogsett, W. Va.	50	16	16	50.1	16
Do	Dam 28, near Huntington, W. Va.	50	16	16	50.0	16
Do	Dam 29, Normal, Ky	50	15	18	54.3	16
Do	Portsmouth, Ohio	50	15	19	54.4	16-17
Do	Maysville, Ky	50	15	19	53.4	17
Do	Cincinnati, Ohio	50	14	20	56.1	17
Do	Madison, Ind	46	16	20	46.8	19
Do	Louisville, Ky	28	16	21	30.5	19
Do	Cloverport, Ky	40	8	25	46.0	21
Do	Evansville, Ind	35	7	(*)	42.9	22
Do	Mount Vernon, Ind	35	9	(*)	43.2	23
Do	Shawneetown, Ill	35	9	(*)	45.8	24
Do	Paducah, Ky	43	16	(*)	47.1	25-26
Do	Cairo, Ill	45	17	(*)	49.4	25-27
Allegheny	Herrs Island Dam, Pa.	22	13	13	24.2	13
Kiskiminetas	Saltsburg, Pa	8	12	12	8.8	12
Stony Creek	Johnstown, Pa	10	12	12	12.0	12
Monongahela	Fairmont, W. Va	25	......	......	24.8	13
Do	Greensboro, Pa	20	12	14	23.6	13
Do	Lock No. 4, Pa	31	13	14	35.0	13
Youghiogheny	Confluence, Pa	10	12	12	10.6	12
Shenango	Sharon, Pa	9	12	12	9.0	12
Muskingum	Marietta, Ohio	32	14	17	38.1	15
Tuscarawas	Norris Point, Ohio	8	12	12	8.0	12
Do	Coshocton, Ohio	8	......	......	7.2	14
Scioto	Circleville, Ohio	7	14	16	11.4	15
Do	Chillicothe, Ohio	14	15	15	14.4	15
Little Kanawha	Glenville, W. Va	22	12	12	27.0	12
Kanawha	Charleston, W. Va	30	......	......	29.7	5
Elk	Sutton, W. Va	30	12	12	30.0	12
Do	Clay, W. Va	18	12	12	20.2	12
Big Sandy:						
Tug Fork	Williamson, W. Va	26	4	4	30.8	4
Levisa Fork	Pikeville, Ky	40	4	4	41.0	4
Miami	Tadmor, Ohio	12	14	14	12.8	14
Green	Lock 6, Ky	30	......	......	29.8	15
Do	Lock 4, Woodbury, Ky.	33	3	10	37.3	6
Do	....do	33	13	21	36.6	15
Do	....do	33	26	28	35.3	27
Do	Lock 2, Rumsey, Ky	34	5	(*)	40.0	21-22
White	Decker, Ind	18	18	23	20.4	22
White, East Fork	Shoals, Ind	20	......	......	19.8	19
White, West Fork	Noblesville, Ind	14	......	......	13.0	15
Do	Elliston, Ind	19	15	19	23.5	18
Wabash	La Fayette, Ind	11	14	18	15.1	16
Do	Terre Haute, Ind	16	......	......	15.4	19
Do	Mount Carmel, Ill	15	16	25	19.2	23
Cumberland	Williamsburg, Ky	22	5	5	22.4	5
Do	Celina, Tenn	45	......	......	44.4	7
Do	Carthage, Tenn	40	4	9	47.4	6
Do	Nashville, Tenn	40	5	13	45.7	10
Do	Lock A, Fox Bluff, Tenn.	43	10	12	43.3	10-11
Do	Clarksville, Tenn	46	8	14	48.7	11-12
Do	....do	46	24	25	46.1	25
Tennessee	Knoxville, Tenn	12	2	7	28.6	5
Do	....do	12	25	26	13.9	25
Do	Loudon, Tenn	25	5	6	30.2	5
Do	Chattanooga, Tenn	33	4	10	47.7	7
Do	....do	33	27	29	34.1	28
Do	Bridgeport, Tenn	24	5	11	30.9	8
Do	....do	24	......	......	23.4	29
Do	Guntersville, Ala	31	5	13	39.4	10
Do	....do	31	25	(*)	36.2	29
Do	Decatur, Ala	21	7	14	23.7	11-12
Do	....do	21	......	......	20.4	30-31
Do	Riverton, Tenn	32	3	(*)	47.0	13
Do	Florence, Ala	18	4	16	24.7	12
Do	....do	18	23	(*)	20.6	28
Do	Johnsonville, Tenn	31	7	(*)	38.9	18
Holston, North Fork.	Mendota, Va	8	2	5	13.6	5
Do	....do	8	25	25	8.2	25
French Broad	Asheville, N. C	4	5	6	4.9	5
Do	....do	4	24	26	4.9	25
Do	Dandridge, Tenn	10	4	6	16.7	5
Clinch	Clinton, Tenn	25	3	7	38.0	5
Do	....do	25	......	......	24.0	19
Do	Kingston, Tenn	25	4	7	33.0	6
Holston	Rogersville, Tenn	14	5	5	17.3	5
Powell	Tazewell, Tenn	20	4	4	22.4	4
Big Pigeon	Newport, Tenn	6	3	5	14.4	4
Hiwassee	Charleston, Tenn	22	4	7	28.3	5
Do	....do	22	25	25	24.2	25
Little Tennessee	McGhee, Tenn	20	4	5	27.7	5

* Continued above flood stage after end of month.

TABLE 6.—*Flood stages in the Mississippi River drainage, except the Ohio River, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates. From—	Above flood stages—dates. To—	Crest. Stage.	Crest. Date.
		Feet.			*Feet.*	
Mississippi	Hannibal, Mo.	13			12.9	31
Do.	New Madrid, Mo.	34	17	(*)	38.6	26-28
Do.	Memphis, Tenn.	35	22	(*)	38.6	31
Do.	Helena, Ark.	42	22	(*)	47.2	31
Do.	Arkansas City, Ark.	42	21	(*)	47.5	31
Do.	Greenville, Miss.	42			40.0	31
Do.	Vicksburg, Miss.	45			43.9	31
Yazoo	Swan Lake, Miss.	25	18	(*)	28.2	31
Do.	Yazoo City, Miss.	25			23.5	31
Cedar	Cedar Rapids, Iowa	14	26	27	17.3	27
Illinois	Peoria, Ill.	16			15.6	21
Do.	Beardstown, Ill.	12	17	(*)	13.6	23-26
Cache	Jelks, Ark.	9			8.9	23-25
James	Huron, S. Dak.	9	25	(*)	12.0	31
Floyd	Merrill, Iowa	13	22	23	14.5	22

*Continued above flood stage after end of month.

A SKEW FREQUENCY CURVE APPLIED TO STREAM GAGE DATA.

By WILLIAM GARDNER REED.

[Dated U. S. Office of Farm Management, Washington, Mar. 7, 1917.]

From a study of the frequency distributions of rainfall amounts it has appeared that nearly all the records show skew frequency polygons, in which the median observation has a smaller value than the mean of all the observations.[1] Similar skewness exists in the frequency distribution of daily gage heights of the upper Paraná at Posadas (Misiones) Argentina ($\phi = 27° 24'$ S., $\lambda = 55° 50'$ W., H = 138 m.). Dr. Wolff, Chief of the Oficina Hydrométrica of Argentina, has computed the frequencies of these gage heights for the 12 years 1904–1915, representing a total of 4,383 observations.[2] His frequency polygon closely resembles those obtained for rainfall amounts. The data have been used in constructing figure 1, which is the frequency polygon and the skew frequency curve for the limiting case computed in the manner suggested by Tolley.

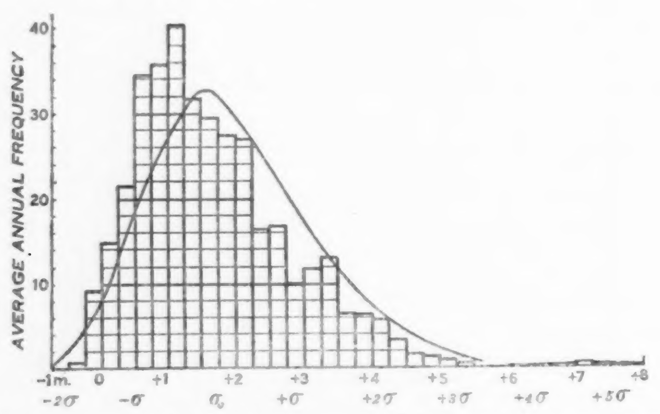

FIG. 1.—Frequency polygon and skew frequency curve for the limiting case for gage heights on the Paraná at Posadas.

Although Wolff has calculated the standard deviation, he has made little use of it in his tabulation. It may be of interest to carry the computation a little further. Using the notation suggested by Tolley, the following values have been obtained:

Quantity.	Symbol.	Value.
Number of observations	n	4383*
Mean gage height	M_o	$5.692 \frac{\text{meters}}{4}$ *
Convenient number near the mean	M	$1.620 \frac{\text{meters}}{4}$ *
Departure from M	d	
Sum of departures	Σd	$+93_1 \frac{\text{meters}}{4}$ *
Average departure from M	$\Sigma d/n$	$+0.2124 \frac{\text{meters}}{4}$ *
Sum of squared departures from M	Σd^2	$+90{,}293 \frac{\text{meters}}{4}$ *
Average square of departures from M	$\Sigma d^2/n$	$+20.6007 \frac{\text{meters}}{4}$ *
Average square of departures from the mean	$\Sigma d^2/n-(\Sigma d/n)^2$	$+20.557 \frac{\text{meters}}{4}$ *
Standard deviation	$\sigma = \sqrt{[\Sigma d^2/n-(\Sigma d/n)^2]}$	$4.525 \frac{\text{meters}}{4}$ *
Sum of cubed departures from M	Σd^3	$+428.063 \frac{\text{meters}}{4}$
Average cube of departures from M	$\Sigma d^3/n$	$+97{,}662 \frac{\text{meters}}{4}$
Average cube of departures from the mean	$\mu_3 = \Sigma d^3/n - 3(\Sigma d/n)(\Sigma d^2/n) + 2(\Sigma d/n)^3$	$+84.580 \frac{\text{meters}}{4}$
Constant representing the value of skewness	$k = \frac{\mu_3}{\sigma_3}$	+0.913

* Values computed by Wolff.

The value of k (+0.913) is of the same sign and the same order of magnitude as that generally found in the case of rainfall amounts. This is to be expected, as variations in stream flow are closely dependent on variations in rainfall. It would be interesting to determine the variations in rainfall over the Paraná drainage basin above Posadas, but this is scarcely practicable owing to the vast extent of the area and the paucity of usable records.

In his statistical computation Wolff—like the North American engineers who have done similar work, notably Allen Hazen,[3] of New York, and R. W. Davenport, of the U. S. Geological Survey—has tacitly assumed that the standard deviation defines the frequency distribution, and has not computed any measure of skewness. He has, however, clearly shown by his polygon (fig. 1) that skewness exists and has not attempted to bring the tails of his polygon, or the summation curve, into arbitrary agreement with the normal curve. Tolley has shown that if skewness of the order here under consideration exists, its amount must be determined by the use of moments higher than the second, σ, if predictions based on the limiting case are to have value. He has also shown that the measure of skewness, k, is determined with as great accuracy as is warranted by the ordinary record when the third moment, μ_3, is used.

The results of this tabulation of the Posadas data furnish a further indication that meteorological and allied phenomena tend to follow definite frequency distributions which can be investigated by modern statistical methods. The application of these methods to stream flow data is obviously of great importance in river and flood studies as well as in irrigation and other investigations upon which depend the utilization of arid and semi-arid regions.

The skewness in the Posadas frequency distribution shows the advisability of using the third moment in the

[1] See *Tolley, H. R.* Frequency curves of climatic phenomena. MONTHLY WEATHER REVIEW, Nov. 1916, **44** : 634–642.

[2] *Wolff, E.* In República Argentina, Oficina meteorológica nacional, Boletín mensual, Buenos Aires, no. 3, marzo 1916, **1** : 40–41.

[3] *See especially* Storage to be provided in impounding reservoirs for municipal water supply. Trans., Am. soc. c. e., New York, 1914, **77** : 1539–1669.

computation of the limiting case. Wolff has not attempted to determine this limiting case nor has he computed the third moment. He has used the second moment only incidentally in determining what he calls a "coefficient of variation," which is not, however, the same quantity as is generally understood by the term. Wolff's "coefficient of variation" is defined as

$$\frac{2\sigma}{s} = \frac{2 \times 1.312 \text{ meters}}{3.993} = 0.567 \text{ meters,}$$

where σ = standard deviation
and $s = h_0\text{max} - h_0\text{min}$
when $h_0\text{max}$ = mean of the annual maxima of gage heights
$h_0\text{min}$ = mean of the annual minima of gage heights
M = mean gage height
$\eta_2 = M + \frac{1}{2}(h_0\text{max} - M)$
$\eta_1 = M - \frac{1}{2}(M - h_0\text{min})$

It is easily seen that η_2 represents a gage height midway between M and h_0 max., and η_1 a height midway between M and h_0 min.

Stages above η_2 are designated as "high-water stages"; they obtained on an average of 55 days a year (1904–1915). Stages below η_1 are "low-water stages"; they obtained on an average of 104 days a year. Stages between these limits are "ordinary stages"; they obtained on an average of 206 days a year (1904–1915).

Although the published material is wholly tabular and graphic, the frequency polygon shows clearly the occurrence of different stages of the Paraná; this polygon, while skewed, is regular without breaks, and the tables furnish data which may be studied by modern statistical methods. If these methods are applied to stream-flow data, it seems probable that the average frequencies of various stages can be determined in the limiting case and these determinations should be of value in studies of floods, water supply, and water rights.

MEAN LAKE LEVELS DURING MARCH, 1917.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Apr. 5, 1917.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during March, 1917:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sealevel at New York	602.33	580.46	571.53	245.17
Above or below—				
Mean stage of February, 1917	−0.09	−0.03	+0.18	+0.09
Mean stage of March, 1916	+0.18	+1.02	−0.34	−0.29
Average stage for March, last 10 years	+0.76	+0.55	−0.26	−0.68
Highest recorded March stage	+0.05	−2.49	−2.32	−2.64
Lowest recorded March stage	+1.67	+1.35	+0.70	+0.87
Average relation of the March level to—				
February level	−0.2	±0.0	+0.1	+0.2
April level	±0.0	−0.2	−0.6	−0.5

*Lake St. Clair's level: In February=574.87; March=574.79.

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL REPORTS FOR MARCH, 1917.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., May 1, 1917.]

TABLE 1.—*Noninstrumental earthquake reports, March, 1917.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds	Remarks.	Observer.
		CALIFORNIA.								
	H. m.		° ′	° ′			*M. s.*			
3	16 00	Table Bluff	40 39	124 15	6	1	11	None	Broke mantle in lighthouse tower.	A. F. Petters.
13	15 15	Salinas	36 36	122 40	3	1		None		Dr. E. D. Eddy
18	12 30	Lone Pine	36 37	118 01	4	1		None		G. F. Marsh.
19	8 50	Lone Pine	36 37	118 01	4	1		None	Windows rattled	Do.
21	17 10	Bishop	37 22	118 24	4	1	25	Rumbling		E. L. Herzinger.
29	8 06	Fillmore	34 23	118 54	4	1			People awakened	Press report.
29	12 59	Stanford University	37 27	122 09	3	1	2	None		Lucile Townley.
		NEVADA.								
28	11 13	Rebel Creek	41 39	117 45	3-4	1	2	None	Buildings shaken	F. Whitaker.
	11 13	Winnemucca	40 58	117 43	3	1	3	None		U. S. Weather Bureau.
		TENNESSEE.								
5	3 07	Knoxville	35 56	83 58	3	1				Press report.
25	22 15	Jefferson City	36 08	83 30	3	1				C. C. Maddox.
	22 15	Talbott	36 08	83 24	3	1	2	Rumbling		M. A. Roberts.
26	13 50	Talbott	36 08	83 24	3	1	2	....do		Do.
27	21 00	Jefferson City	36 08	83 30	5	1			Shook buildings	C. C. Maddox.
		TEXAS.								
26	19 56	Panhandle	35 20	101 20	6	2	20	Rumbling	Caused considerable alarm	G. F. L. Bishop.
	19 56	....do	35 20	101 20	6	2	8	....do	Plaster cracked	J. Sid O'Keefe.
		WASHINGTON.								
28	17 05	Ashford	46 48	121 56	5	2	2	Rumbling	Shook buildings	J. B. Flett.
		WYOMING.								
10	14 24	Rawlins	41 47	107 15	4	2	20	Rumbling	Some ran out of houses	C. J. Ehrenfeld.
	14 34	Rock River	41 34	105 59	2	1		....do		M. W. Gordon.

TABLE 2.—*Instrumental seismological reports, March, 1917.*

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat. 57° 03′ 00″ N.; long., 135° 20′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: $\begin{cases} E & 10 & 16 \\ N & 10 & 15 \end{cases}$ (V, T_0)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6		eP_N	2 13 26					P and S confused by microseisms. Only a few long waves certain on E-W.
		S_N?	2 22 44	8				
		S_E?	2 22 46					
		L_N	2 34 16	18				
		L_E	2 35 14					
		M_E	2 36 02	13	10			
		M_N	2 39 22	13		40		
		F_E	2 41 ..					
		F_N	2 54 ..					

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: $\begin{cases} E & 10 & 13.9 \\ N & 10 & 19.1 \end{cases}$ (V, T_0)

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6		P	3 11 10	4				
		S_E	3 15 23	6				
		S_N	3 15 23	7				
		L_N	3 18 36					
		L_E	3 18 42	15				
		M_E	3 19 30	13	730			
		M_N	3 20 50	15		230		
		C	3 23 ..	11				
		F	3 59 ..					
26		e_E	14 04 09	4				
		e_N	14 04 16	3				
		M_E	14 05 04	8	80			
		M_N	14 05 20	7		20		
		F_N	14 13 ..					
26		e_E	14 28 47	3				
		e_N	14 28 58	2				
		M_N	14 29 54	6		10		
		M_E	14 29 56	8	20			
		F_E	14 38 ..					
		F_N	14 40 ..					

TABLE 2.—*Instrumental seismological reports, March, 1917*—Continued.

California. Berkeley. *University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Mar. 2					*250	*300		Tremors recorded during 24 hours preceding 15h on dates given.
9					*400	*400		
20					*200	*250		
22					*200	*300		
24					*400	*400		
25					*100	*100		
26					*300	*400		
27					*200	*200		
28					*300	*400		
29					*100	*200		
30					*100	*100		
31					*200	*400		

* Amplitude on instrument.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station.

A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation. 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Mar. 5–6								Evident activity at intervals during day, especially on N-S.
6		L_N	3 16 ..					Quite discernible but phases obscure. Hardly any record on E-W.
		M_N	3 17 ..	4–8		*500		
		F_N	3 19 ..					
6		L	3 22 ..			*500		Clearer and stronger than preceding. Probably new quake. No preliminaries can be seen.
		M_E	3 23 ..	4–8				
		M_N	3 23 ..	10		*750		
		F_E	3 26 ..					
		F_N	3 28 ..					
30		L_N	22 22 ..					Wavelets and thickening of penmarks. Maximum rather doubtful.
		M_N	22 26 ..					
		F_N	22 55 ..					

* Trace amplitude.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum, undamped. Mechanical registration).

Instrumental constants: V 110, T_0 6.4

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Mar. 3	I_r	P_N?	10 19 51				3,810?	
		S?	10 25 27					
		L	10 30 20	20				
		F	11 00 00					
6	I_r	P_N?	3 12 17				3,515?	All phases masked by microseisms.
		S	3 17 35					
		L	3 23 50	15				F lost in microseisms.
15		S?	0 54 12					Phases indeterminate; small amplitude.
		eL	1 01 27					
		L	1 05 08	16				
		L	1 08 00	20				
		L	1 13 30	20				
		L	1 18 40	16				
		F	1 45 00					
26	I_r	P	14 12 21				2,510	
		S	14 16 27					
		L	14 19 00					F in succeeding quake.
26	I_r	P?	14 37 30				2,330?	
		S	14 41 21					
		L?	14 44 40					
		F	14 55 00					
29	I_u	P	2 08 05				6,240	
		PR?	2 11 11					
		S	2 15 54					
		L	2 24 52	20				
		F	2 40 00					

District of Columbia. *Washington. Georgetown University.*
F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants:

	V	T_0	ϵ
E	165	5.4	0
N	143	5.2	0
Z	80	3.0	0

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
Mar. 3		e	10 23 26					Gram very doubtful because of mircoseisms, especially on E-W.
		S_N?	10 29 12					
		S_E?	10 29 32					
		L_N	10 34 12					
		L_E	10 34 15					
		F	10 57 00					
6		e?	3 12 24					Heavy microseisms present.
		S_E?	3 18 45					
		S_N?	3 18 49					
		eL_E	3 26 20					
		eL_N	3 26 26					
14								Very heavy thickening of tracing from 23h 24m to 23h 39m. Quite certain of seismic origin. Phases not discernible.
15		e	1 01 21					Heavy microseisms present. Phases difficult to discern.
		eL	1 12 03					
		F	1 22 00					
26		e_E	14 12 20					Confused by heavy local disturbance. Phases on E-W less distinct.
		e_N	14 12 40					
		S	14 16 46					
		L_E	14 19 32					
		L_N	14 19 40					F lost in second quake.
26		e	14 36 42					Phases difficult to discern; microseism present.
		S_E	14 41 22					
		S_N	14 41 30					
		F	15 00 00					
29		e	2 08 23					Microseisms present. E-W very difficult. All phases doubtful.
		S?	2 11 23					
		eL?	2 16 23					
		F	2 36 —					

TABLE 2.—*Instrumental seismological reports, March, 1917*—Continued.

Hawaii. *Honolulu.* *Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neuman.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 18.5

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 1		e	5 40 24					
		M	5 43 18		*100			
		F	5 50 00					
3		e	10 52 12					
		M	10 54 06		*100			
		F	10 55 24					
4		e	6 20 42					
		M	6 23 48		*100			
		F	6 37 12					
6		eS?	3 17 00					No distinct phases: resembles air tremors.
		L	3 25 00		*50			
		F	4 05 00					
15		P	0 23 54					Actual maximum at 0^h 32^m 12^s (*1300) probably caused by observer entering room to observer time break.
		S?	0 31 18					
		L?	0 44 36					
		M	0 49 06		*800			
		C	1 05 24					
		F	1 54 00					
16		e	12 04 42					
		M	12 09 12		*100			
		F	12 14 00					
21		e	8 16 24					
		M	8 20 24		*100			
		F	8 23 06					
26		e	14 22 54					
		M	14 24 24		*100			
		F	14 27 42					
28		P?	5 20 12					
		S?	5 25 36					
		L	5 30 12					
		M	5 33 18		*200			
		C	5 35 24					
		F	5 43 —					
29		P?	2 20 42					P and S doubtful: may be artificial disturbance.
		S?	2 27 42					
		L	2 42 18					
		M	2 46 00		*200			
		C	2 47 42					
		F	2 57 —					

* Trace amplitude.

Kansas. *Lawrence.* *University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants.. E: V 177, T_0 3.4, ϵ 4.1; N: V 205, T_0 3.4, ϵ 4.1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6		iP	3 11 17		2	4		P and S unusually prominent.
		iS_E	3 15 30		6			
		iS_N	3 15 31			11		
		eL?	3 20 37					L almost insignificant.
		M_E	3 24 50		2			
		M_N	3 26 17	8-10		2		F lost in microseisms.
26		P	14 05 02					S indeterminable.
		L	14 10 27					
		M_N	14 11 33			4		
		M_E	14 11 42		4			
		F	14 28 00					
26		P	14 29 43					S indeterminable.
		L_E	14 35 02					
		L_N	14 35 03					
		M_N	14 35 18			3		
		M_E	14 36 16		2			
28		L?	19 55 24					Isolated phase.
28		P	19 56 11					
		L	19 56 44					
		M	19 57 02		2	2		
		F	20 02 —					

Maryland. *Cheltenham.* *Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. E: V 10, T_0 32; N: V 10, T_0 27

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6		P_N	3 12 25	4				Phases obscured by miseismic tremors.
		S_N	3 17 09	6				
		S_E	3 17 54					
		L_N	3 23 37	13				
		L_E	3 24 20	15				
		M_N	3 27 34	12		40		
		M_E	3 27 55	10	15			
		C	3 31 ..	10				
		F_E	3 41 ..					
		F_N	3 53 ..					
26		e_N	14 17 05	4				Barely perceptible.
		e_E	14 17 37	4				
		F	14 24 ..					

Massachusetts. *Cambridge.* *Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.. E: V 80, T_0 23, ϵ 0; N: V 50, T_0 25, ϵ 4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 3		*O*?	*10 13 58*				2,930	Distance from N-S=2,880 *km.* N-S*O*= 10^h 13^m 47^s.
		eP_E?	10 19 38					
		eP_N	10 19 42	2				
		S_E	10 24 16	6				
		S_N?	10 24 42					
		eL_E	10 27 16	20				
		L_N	10 28 00					
		L_E	10 28 34	14				
		L_E	10 31 06	12				
		C	10 33 14	10				
		F	11 18 ..					
6		*O*	*3 05 19*				3,680	Masked by microseisms of 4.8 seconds period. N-S record illegible.
		P_E?	3 12 13					
		S_E	3 17 41					
		eL_E	3 22 02	20				
		L	3 26 43	12				
		C?	3 31 29					
		F?	4 01 ..					
15		eL_E	1 01 43	14				*O*? P and S lost in tangled lines of diurnal waves. Maximum weak. N-S too faint.
		L_E	1 05 37	20				
		M_E?	1 09 10	18				
		F?	1 24 ..					
26		e_N	14 19 30	3				*O*?
		e_E	14 19 40	4				
		L_E?	14 20 37	10				
		L_E	14 22 30	10				
		L_N?	14 23 21	6				
		L_E?	14 29 11	6				
		L_E	14 32 14	6				
		F?	14 40 ..					
26		L_E?	14 44 44	13-10				
		F	14 51 ..					
29		e_E?	2 17 53	6				Not recognizable on N-S.
		eL_E	2 20 11	24				
		L	2 28 04	20				
		L	2 46 59	10				
		F?	3 00 00					

TABLE 2.—*Instrumental seismological reports, March, 1917*—Continued.

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert, 80 kg. astatic, horizontal pendulum.

Instrumental constants.. V 80, T_0 7, ϵ 5:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6	II_r	P	3 11 18				2,100	
		S	3 14 48					
		L	3 15 36					
		F	3 41 00					
26								Two quakes registered between 14h and 15h. Times wanting owing to contacts not working.

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants.. V 80, T_0 7, ϵ:1 5:1

(Report for March, 1917, not received.)

New York. *Fordham. Fordham University.* Daniel H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..	V	T_0	ϵ
E	72	6.6	1.5:1
N	72	7.1	3.8:1

(Report for March, 1917, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants..	V	T_0	ϵ
E	13	22	4:1
N	14	25	4:1

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 3		e_E	10 27 43	5				
		e_N	10 27 46	4				
		L_E	10 29 48	20				
		L_N	10 29 57	16				
		F_E	10 43 ..					
		F_N	10 49 ..					
15		eL_E	1 06 59	22				
		eL_N	1 08 13	20				
		F_E	1 26 00					
		F_N	1 38 00					

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants.. V 10, T_0 20

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6		P_N	3 09 40				1,080	Direction?
		P_E	3 09 44					
		S_N	3 10 26					
		S_E	3 10 48					
		L_N	3 12 50					
		M_N	3 12 57			100		
		L_E	3 13 04					
		M_E	3 13 06		50			
		F_E	3 36 12					
		F_N	3 43 02					
13		P_E	9 45 02				185	Direction?
		P_N	9 45 04					
		L_N	9 45 32					
		L_E	9 45 34					
		M_N	9 45 34			100		
		M_E	9 45 36					
		F_N	9 47 04					
		F_E	9 47 12					
29		P_N	2 05 00				1,225	Direction?
		P_E	2 05 01					
		L_E	2 07 29					
		M_E	2 07 49		20			
		L_N	2 09 04					
		M_N	2 09 44			160		
		F_N	2 23 04					

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..	V	T_0
E	10	17.5
N	10	18

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6		P_E	3 12 36	5				Initial phases obscured by wind tremors.
		L_N	3 20 24	14				
		L_E	3 20 34	19				
		M_N	3 23 58	16		30		
		M_E	3 24 26	16	20			
		F	4 13 ..					
29		P_N	2 07 05	8				Initial phases obscured by wind tremors. Barely perceptible on E-W.
		S_N	2 11 50	9				
		L_N	2 16 00	20				
		M_N	2 21 30	15		30		
		F	2 51 ..	13				

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants..	V	T_0
E	10	15
N	10	16

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 6		S?	3 18 24					Very feeble record. F lost during changing of sheets.
		L	3 27 16	22				
15		L_E	1 07 00	20				Other phases indistinguishable.
		F	1 20 00					
26		e	14 19 18					
		F	14 30 00					
26		e	14 44 00					
		F	14 52 00					

TABLE 2.—*Instrumental seismological reports, March, 1917*—Continued.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80kg. vertical seismograph.

Instrumental constants.. V 120 T_0 26

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 3	....	*O*	*10 14 20*				2,840	
		P_N	10 20 01					
		P_E	10 20 04					
		S_N	10 24 32					
		S_E	10 24 37					
		eL	10 27 18	20				
		L	10 31 00	14				
		L	10 40 00	10				
		F	11 10 00					
6	....	*O*	*3 05 18*				4,000	Distance approximate. Seismograph clock stopped. Record from deformation instrument where 17 mm.=1 hour.
		P	3 12 36					
		S	3 18 24					
		L	3 22 18					
		F	4 20 ..					
15	....	P_N?	0 41 14				7,100?	
		P_E?	0 41 16					
		S_E?	0 49 50					
		S_N?	0 49 51					
		L	1 02 00	20				
		L	1 06 00	20				
		L	1 11 00	19				
		F	1 30 00					
26	....	e	14 18 14					
		i	14 18 34					
		eL_E?	14 19 37	8				
		L_E?	14 23 00	8				
		F	14 35 00					
26	....	e_E	14 42 48					
		i_N	14 43 07					
		i_E	14 43 08					
		eL_E?	14 44 09	8				
		L_E?	14 46 00	8				
		F	14 57 ..					

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom=0.50″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 3	....	eL	10 26 54					P and S not recorded.
		L	10 29 54					
		M	10 32 06					
		M	10 34 30		*800			
		F	10 44 30					
6	....	e	3 16 00					
		L	3 25 18					
		M	3 26 18		*1200			
		F?	4 44 48					
15	....	iP	0 37 30		*200			Movements gradually increased from first L to M.
		S	0 49 48					
		eL	0 59 18					
		M	1 11 48		*800			
		L	1 34 12					
		L	2 18 42					
		L	2 20 54					
		F	2 25 00					
16	....	eL	10 42 00					Gradual thickening.
		M	10 44 48		*200			
		F	10 50 36					
26	....	L	14 17 24		*200			
		F	14 27 00					
29	....	P	2 21 00					
		S	2 25 42					
		L	2 27 24					
		L	2 30 18					
		M	2 31 18		*300			
		F	2 59 36					

* Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instruments: Wiechert, vertical. Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation: 1 mm. swing of boom =0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Mar. 3	....	L	10 25 06					
		M	10 42 27		*200			
		F	10 53 52					
6	....	P?	3 19 42					
		S?	3 23 10					
		L	3 27 38					
		M	3 33 05		*1500			F uncertain.
		VERTICAL			A_Z			
		P	*3 14 00*	*5*				*S?*
		L	*3 28 00*	*7–8*				
		M	*3 33 00*	*11*	*60*			
		F	*3 42 30*					
15	....	L	0 32 43					
		M	0 59 00		* 200			
		F	1 36 42					
16	....	M?	10 57 34					May be M part of long-distance quake.
26	....	*P?*	14 10 37					
		L	14 13 30					
		M	14 15 58		* 400			
		F	14 21 52					
29	....	P?	2 33 27					
		S?	2 35 56					
		L	2 38 59					
		M	2 41 53		* 500			
		F	2 57 45					

* Trace amplitude. A_Z=true earth movement in μ.

SEISMOLOGICAL DISPATCHES.[1]

Knoxville, Tenn., March 5, 1917.

A shock was felt here last evening (Mar. 4) at 9:07 o'clock. This is the second seismic disturbance felt in Knoxville and vicinity within the past 10 days. No damage resulted from the slight quake of Sunday evening. (Assoc. Press.)

[1] Reported by the organization indicated and collected by the seismological station of Georgetown University, Washington, D. C.

SECTION VI—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following books have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological and seismological work and studies:

Andrews, A. W.
Text-book of geography. London. 1916. xi, 655 p. figures. tables. 19cm. [Climate, p. 36-68.]

Angot, Alfred.
Traité élémentaire de météorologie; 3me éd. rev. et corrigée. Paris. 1916. vii, 415 p. figures. 25cm.

Bates, Carlos Glazier.
The windbreak as a farm asset. Washington. 1917. 16 p. (incl. title-page) illus. 23½cm. (U. S. Dept. of agriculture. Farmers' bulletin 788.) "Contribution from the Forest service."

Blue Hill observatory.
[Report of the director] 1915-16. (Excerpted from: Official register of Harvard university. Reports of the president and the treasurer of Harvard college, 1915-16, p. 236-239. Cambridge. 1917.)

Chamberlain, Basil Hall.
Things Japanese, being notes on various subjects connected with Japan for the use of travellers and others; 5th ed. rev. London. 1905. vi [1] 552 p. fold. map. 22cm. [Climate, p. 95-100 with table of precipitation.]

Cochrane, John L.
Safety-first train. Washington. 1917. 46 p. (incl. title-page) illus. map. tables. 23cm. (At head of title: Department of the interior. Office of the secretary.) [Weather bureau, p. 35-37.]

Delgado de Carvalho, Carlos M.
Météorologie du Brésil. Londres. 1917. xix, 527 [1] p. plates. diagrams. charts (partly fold.) 2 fold. maps. 24cm. (Bibliographie, p. 518-525. Préface de Sir W. Napier Shaw.)

Föyn, N. J.
Das Klima von Bergen. Theil 2. Lufttemperatur. Bergen. 1916. 88 p. (incl. title-page) tables. 23 cm. (Sonderabdruck aus Bergens Museums Aarbok, 1915-16. Naturvidenskabelig række. Nr. 4. On cover: Mitteilungen vom Meteorologischen Observatorium in Bergen.)

Friez, Julien P. & sons.
Illustrated catalog standard meteorological instruments and apparatus manufactured by Julien P. Friez & Sons, Belfort meteorological observatory. Baltimore. [c 1917] 58 p. (incl. title-page) front. (port.) illus. 23½cm. (At head of title: Catalog.-B.)

Geitel, Hans.
Zur Frage nach dem Ursprunge der Niederschlagselektrizität. (Photographed from Physikalische Zeitschrift, v. 17, 1916, p. 455-464.) 27½cm.

Reeds, Chester A.
A perplexing phenomenon—mirage. illus. diagrams. 25cm. (Excerpted from the American museum journal, v. 16, Dec. 1916, p. 513-524.)

Spain. Observatorio central meteorológico.
Resumen de las observaciones meteorológicas efectuadas en las estaciones del servicio meteorológico español, durante los años 1904 y 1905. v. 10. Madrid. 1916. x [1] 192 p. [1] tables. 25cm.
Resumen . . . durante el año 1914. v. 9. Madrid. 1916. xc [1] 488 p. [3 1] tables. 25cm.

U. S. National advisory committee for aeronautics.
Second annual report . . . for the fiscal year ended June 30, 1916. Washington. 1917. 630 p. plates. figures. 25½cm. (At head of title: Aeronautics.)

Wallis, B. C.
Rainfall of Java. (Reprinted from the Scottish geographical magazine, v. 33, March, 1917, p. 108-119. Bibliography, p. 119.) 25cm.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

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Ward, Robert DeC[ourcy]. The prevailing winds of the United States. p. 99-119. Bibliography, p. 117-119.

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Culver, Frank S. Performance of two successful windmill generating plants. p. 367-369.

Engineering news-record. New York. v. 78. April 26, 1917.
Horton, Robert E. A new evaporation formula developed. p. 196-199.

Franklin institute. Journal. Philadelphia. v. 183. April, 1917.
Whitehead, J. B. The electric strength of air and methods of measuring high voltage. p. 433-451.

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Veeder, M[ajor] A[lbert]. The relation between solar and terrestrial meteorology. p. 303-316.

Journal of electricity, power and gas. San Francisco. v. 37. September 23, 1916.
Shaw, S. B. Rainfall and agricultural power use. p. 242-243. [Relation of rainfall to electric power and for irrigation pumping.]

Manufacturers record. Baltimore. v. 71. March 22, 1917.
[Easton, Edward C.] Saving early truck and fruit through warnings sent by Uncle Sam. p. 57.

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Nakamura, Sawemontarô. On the Hakone earthquakes in January, 1917. p. 15-22.
Hasegawa, K. The Formosa earthquake on January 5, 1917. p. 23-24.

Royal society of Edinburgh. Proceedings. v. 36. 1915-1916.
Aitken, John. The dynamics of cyclones and anticyclones. pt. 3. p. 174-185.

Photographic journal. London. v. 57. March, 1917.
Cox, Bertram. Some observations on clouds. p. 124-132.

Science. New York. v. 45. April 20, 1917.
Merrill, George P. The unit of pressure. p. 385.

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Ducasse, L. Possible influence of a railway on thunderstorms in a hill country. p. 26. [Abstract from Electrician.]

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Edholm, C. L. Airmen and the Weather Bureau—partners. The meteorological work undertaken at the San Diego army aviation school. p. 342; 355.

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Palmer, Andrew H. An eruption of Lassen peak. Meteorological and seismological considerations. p. 216-217. [Repr. from MONTHLY WEATHER REVIEW.]

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Störmer, Carl. Preliminary report on the results of the aurora-borealis expedition to Bossekop in the spring of 1913. (Fifth communication.) p. 153-156.
Störmer, Carl. Summary of results of the aurora-borealis expedition of 1913 to Bossekop, Norway. p. 157-168.
Vegard, L., *and* Krognes, O. The height of the aurora-borealis according to observations at the Haldde observatory, Norway. p. 169-173.

Tôkyô mathematico-physical society. Proceedings. Tôkyô. 2d ser. v. 9. March, 1917.
Otobe, Kôkichi. Equation of horizontal rainbows. p. 63-67. [See this REVIEW, April, 1917.]

U. S. National advisory committee for aeronautics. Washington. 1916.
Marchis, L. Experimental researches on the resistance of air. p. 555-630. [Bibliography, p. 630.]

Weltall. Berlin. 15. Jahrgang. Nov.-Heft. 1916.
Tippenhauer, L. Gentil. Ueber den Zusammenhang des Barometerstandes mit dem elektrischen Zustande der Atmosphäre in den Tropen. p. 39-43.

Pontificia accademia romana dei Nuovi Lincei. Atti. Roma. anno 69. 1915-1916.
Galli, Ignazio. Di due recenti fulmizaioni nella provincia Romana Nota 15. p. 105-108.
Gabelli, Lucio. L'influenza delle basse temperature sulle così dette fioriture invernali. p. 125-135.
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Marchi, Luigi de. Sulla dispersione sismica. p. 134-136. [Reply to Oddone.]
Agamennone, G., *and* Cavasino, A. La velocità di propagazione del terremoto ligure del 23 febbraio 1887. p. 167-171.

SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF MARCH, 1917.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, D. C., May 2, 1917.]

PRESSURE.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds are graphically shown on Chart VII, while the average values for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

At the beginning of March relatively high pressure prevailed over practically all districts, except in the extreme eastern Canadian Provinces, where it was near or slightly below the average. High pressure continued for the next several days in most sections, except in the Southeast and far Northwest, where lower pressure obtained. About the middle of the first decade a large area of low pressure moved from the Northwest and overspread most eastern districts, continuing for several days. During the second decade several extensive low and high pressure areas moved in rather rapid succession across the country, resulting in marked pressure changes from day to day in many sections. Toward the latter part of the second decade and during the first few days of the third relatively low pressure obtained in most central districts, while in the Southeast and over the central and southern Rocky Mountain region and to the westward it was generally above the average. During the latter half of the third decade the pressure was generally below the normal in the northern half of the country, while in the southern half it was, as a rule, above the average.

The month closed with pressure above the normal in all southeastern districts and in the central Plateau and Pacific Coast States. Elsewhere it was near or below the average.

For the month as a whole the barometric pressure was below the normal in the upper Lake region, the upper Mississippi and lower Missouri valleys and over the Canadian Northwest, but the departures were generally not large. Over all other portions of the country the average pressure was above normal, the departures being quite marked in the districts to westward of the Rocky Mountains.

The distribution of the HIGHS and LOWS favored westerly and northwesterly winds in the New England and Middle Atlantic States, the upper Mississippi, and Missouri valleys and over the southern Rocky Mountains region, while southerly and southwesterly winds were of frequent occurrence in the South Atlantic and Gulf States, the lower Lakes region, the Ohio and middle Mississippi valleys. Elsewhere variable winds prevailed.

TEMPERATURE.

March opened with cold weather and widespread frosts in the far Southwest and the Pacific Coast States. On the morning of the 4th temperatures considerably below 0°F. prevailed in the Dakotas and Minnesota, and they were also unseasonably low throughout the Plains States as far south as central Texas. By the morning of the 6th the cold weather had overspread the eastern part of the country, with widespread killing frosts in portions of the Gulf States, Georgia, and South Carolina.

For the first decade as a whole the weather was almost everywhere colder than the normal, especially in the Plateau region and Montana. During the second decade temperatures were below the normal in New England, the upper Mississippi and Missouri Valleys, the Central Plains States, Montana, and west of the Continental Divide, while in most of Texas it was warmer than the average. However, about the 18th heavy frosts occurred in northeastern Texas and freezing temperatures obtained to the northwestward and westward, and on the 19th killing frosts extended to North Carolina and northern Georgia, and light to heavy frosts in almost all other parts of the eastern cotton belt, except Florida. After the 20th temperatures above the normal were the rule, except in the north Pacific States and the Plateau region. In most of the middle and northern Plains States and thence eastward to the Atlantic this period was decidedly warmer than normal.

For the month as a whole the temperature was slightly above the normal in most eastern districts, while in the western portions of Nebraska and the Dakotas, and from the Rocky Mountains westward, it was colder than normal.

PRECIPITATION.

At the beginning of the month rain was falling in most of the cotton belt, being heavy in many portions of Georgia, Tennessee, Mississippi, Alabama, and Arkansas, and during the next few days snow or rain became widespread, extending northward to the Lakes region. About the middle of the first decade rather heavy rain fell in parts of Louisiana and Florida and widespread precipitation occurred throughout most sections to the northward and eastward. Good rains fell in southern Florida about the 7-8th, breaking a prolonged and severe drought in that section, and toward the end of the decade widespread rains again occurred in the Pacific States. During the first few days of the second decade there was rather heavy precipitation in most northern districts, with considerable snow in Michigan. Also toward the middle of the decade an area of low pressure moved from the Southwestern States to the Lakes region, causing heavy precipitation in some sections, and a few days later another storm followed nearly the same path, causing heavy snow in central Nebraska and northeastward to the upper Lakes region.

During the third decade much rain and snow occurred in some of the far Western States, specially in the more northern districts, and important rains occurred from the Middle Plains States eastward on the 22d-24th, and again in the eastern districts on the 27th, being specially heavy in Tennessee and the adjoining States to the southward, and also in the Carolinas and much of New England.

For the month as a whole, in southwestern districts from Texas and Oklahoma to southern California rainfall was generally very light, several areas having no precipitation at all. In southern Nevada and Utah, most of the Dakotas, eastern Montana, and northern Minnesota, most of Colorado, Kansas, and southern Nebraska, and portions of the Florida Peninsula, the

totals were much less than normal. In southeastern districts the falls were decidedly large, save in most of Florida and near the Gulf and Atlantic coasts. In much of Arkansas, in southern Indiana, the Virginias, Maryland, and New Jersey the totals were generally more than 4 inches, and over the southern Appalachian districts a large area received more than 10 inches.

SNOWFALL.

Considerable snow fell during the month in portions of the Ohio Valley and to the northeastward and also from the upper Lake region westward, as well as in many of the mountain regions of the West, particularly in western Montana and portions of Idaho, Washington, Oregon, California, and Colorado. At Duluth, Minn., in 24 hours on the 13-14th, 21 inches fell, being the greatest 24-hour snowfall of record at that place. Again on the 16-17th, 15 inches fell, which, with the unmelted snow from previous falls, made 40 inches on the ground, the greatest depth of record at that place.

To the eastward of the Rocky Mountains the increasing warmth melted the snow rapidly so that by the end of the month only small areas in the vicinity of the upper Lakes region remained snow-covered. In the western mountain districts the season of snowfall appears to have closed with a large supply of well-packed snow in nearly all of the higher ranges specially over the northern districts, and prospects for an abundant supply of water in the more important irrigation districts seemed assured.

RELATIVE HUMIDITY.

The relative humidity for the month as a whole was generally above the normal in the southern half of New England and from the upper Lakes region westward, including the northern Rocky Mountain and Pacific Coast States. On the other hand, the atmosphere was relatively drier than the average for March in the southern half of the country, as well as in the central valleys and the lower Lakes region, the deficiency being unusually great in portions of the Plains region and the far Southwest.

GENERAL SUMMARY.

The month was favorable for farm work in Florida but was unfavorable in practically all other Southeastern States because of frequent rains, while in Texas and Oklahoma germination was delayed by the lack of rainfall. Most spring work was delayed on the Pacific coast.

The weather was generally favorable for the development of winter wheat over the States from Missouri eastward and also in eastern Kansas and small portions of Oklahoma and in the Central and Northern Rocky Mountain States. Elsewhere the conditions were generally unfavorable.

The planting of cotton was delayed by frequent heavy rains east of the Mississippi River. However, during the latter part of the month the weather was more favorable and planting progressed rapidly in some of the more southern districts. Corn and potato planting was well advanced in the South and some progress had been made in planting these crops in the more central sections.

The shortage of feed and the heavy snow cover during much of the preceding winter in the northern Rocky Mountain and Great Plains States have caused severe loss of live stock, specially in Montana, but farther south although the ranges were poor and dry the loss was not so great. Some damage resulted to fruit in the Gulf States by the cold of March 3d-4th, and the frequent frosts in California injured almonds and apricots.

SEVERE LOCAL STORMS.

Ths following notes on severe storms have been extracted from reports made by officials of the Weather Bureau:

Alabama.—Tornadoes occurred at Prairieville, near Gallion, Hale County, about 1 p. m., on March 26, and in northeastern Crenshaw and northwestern Pike counties about 12:30 a. m. on the 27th. The Prairieville storm, in a path about one-half mile wide, destroyed about 20 houses and killed one person. The Pike-Crenshaw tornado moved from southwest to northeast over an area about one-half mile wide by 25 miles long. It wrecked the little town of Petrey, Crenshaw County, killing four persons. Farther along its course in Crenshaw, and in Pike County, in the vicinity of Ansley, Harmony, and Orion, five others were killed and many more injured.

Arkansas.—A tornado, in which six persons were killed, a number injured, and a great deal of property destroyed, crossed Clark, Dallas, and Grant counties on March 20. Two tornados occurred on the 31st—one at Mellwood, in Philips County, whereby one person was killed, several injured, and several houses destroyed; and one at Belleville, in Yell County, resulting in one person killed and several buildings destroyed.

Indiana.—On March 11 a tornado crossed parts of Henry and Wayne Counties, reaching the southern part of the city of New Castle at 3:05 p. m. and swept its way through that city, first in an easterly and then in a southeasterly direction, traversing a distance of about 20 blocks in 2 or 3 minutes. The time of its passage at a given point was only a few seconds, and was described by several persons as being instantaneous. The width of the path of greatest damage was from 300 to 500 feet, and therein destruction was practically complete. A number of buildings, with their entire contents, were broken up completely and blown away. Numerous houses for some distance on either side of the tornado path were damaged to a lesser extent. Twenty-one people in New Castle were killed or died from the effects of the tornado and as many more were seriously injured, while between 50 and 100 received minor injuries. Seventy-five buildings were destroyed and about 275 damaged, the property loss being about $576,500.

After passing through the city, the tornado continued east-southeastward, reaching a point about 1 mile south of Millville at 3:15 p. m., and about one-half mile south of Hagerstown, 11 miles from New Castle, at about 3:30 p. m. Near the former location 1 person was killed, 2 injured, and property damaged to the amount of about $10,000; at the latter location 2 persons were killed and property loss was about $3,500. After passing Hagerstown, the storm continued in the same general direction, but decreased in speed and intensity and lost its tornadic character before reaching Green Forks, 7 miles distant.

Heavy rain, with hail in many places, accompanied the tornado along its entire course and in New Castle undoubtedly served to prevent fires that might otherwise have occurred. There were many evidences of tornadic action. The funnel-shaped cloud was well-marked and the penetrating, rushing roar of the wind was heard at a distance of several miles. Many building walls were forced outward as a result of the sudden expansion of the air within as the center of the tornado passed.

On March 23, 1917, a tornado moved in a nearly straight path in an east-northeast direction, cutting a swath through the entire north side of the city of New Albany. The width of the path of practically total destruction varied between 1,000 and 1,500 feet with an area along each side of from 600 to 1,000 feet in which there was a great deal of damage, mostly in spots. The length of the path of the storm was about three and one-half miles, although many articles of furniture and clothing and other débris were found many miles from New Albany, whence they came. In New Albany 41 people were killed or died from injuries received, and several hundred others were injured. Between 200 and 300 houses were destroyed including several manufacturing plants, while several hundred more houses were damaged. Practically 2,500 people, including from 350 to 400 families were made homeless. The storm began at 3:08 p. m. and lasted about five minutes. The property damage was estimated between one and one and a half million dollars. A more detailed report of this storm will appear in a later issue of the MONTHLY WEATHER REVIEW.

In addition to the above, a number of other storms of tornadic character occurred in different parts of the State on the 23d, some of which are as follows:

Over the southern part of Sullivan County, south of Carlyle, at about 1:15 p. m. a tornado swept from west to east, a distance of about 18 miles, killing one man and injuring about 20 others with property damage about $150,000. Width of path of greatest destruction about one-fourth mile.

In the northern part of Hendricks County, west of Pittsboro, at about 1:30 p. m., a tornado did considerable damage to buildings, orchards, etc., width of path of greatest destruction from 40 to several hundred feet.

In the western part of Grant County, west of Swayzee, about 2:30 p. m., a tornado swept southwest-northeast, doing damage in a path about 40 rods wide. One person was injured.

In the eastern part of Delaware County, southeast of De Soto, at about 3:30 p. m., a tornado moved southwest-northeast doing damage to buildings and trees in a path about 700 feet wide. Two persons were injured and property damaged about $2,500.

In the northern part of Adams County, near Preble and Magley, at about 2:55 p. m., a tornado swept a path about 200 feet in width, causing property damage amounting to about $5,000, and injuring two people.

In the central part of Harrison County, about 1 mile north of Corydon, at about 3:30 p. m., a tornado having a path from one-fourth to one-half mile wide did considerable damage to buildings on farms. Twenty persons were injured, but none were killed.

Illinois.—On March 23, storms of a tornadic nature visited Johnson and Crawford counties. In the first-named, buildings were damaged somewhat and two persons were injured, but in the southeastern part of Crawford County the storm was the worst on record. Several persons were injured, and the property loss amounted to several hundred thousand dollars.

Kansas.—Tornadoes were reported near Carlyle and Howard on the evening of March 22. The one near Carlyle occurred about 8 p. m. and moved from southwest to northeast. The width and length of its path could not be ascertained, though neither was great. The funnel-shaped cloud was distinctly seen. No person was injured, but property damage amounted to about $2,500.

The tornado near Howard on the same date formed to the southwest of that town between 5 and 6 p. m. and moved northeastward, passing in the vicinity of the town itself. The characteristic cloud was plainly seen. The damage was confined to small farm buildings and did not amount to more than a few hundred dollars. No persons were injured.

Kentucky.—The tornado that visited New Albany, Ind., on March 23, jumped to Harrod's Creek, Ky., as will be reported in the REVIEW for April, 1917.

Ohio.—On March 11, 1917, a tornado occurred in the vicinity of Cincinnati, and two others passed over western Montgomery County. A detailed report of these storms will be found on pages 115–8 of this issue of the REVIEW.

Tennessee.—A severe local storm did considerable damage near Pleasant Point and Dunn, in Lawrence County, during the afternoon of March 16. A number of houses and barns were wrecked and several persons were seriously injured, one probably fatally.

About 5 p. m. of the 23d a storm moved in a northeasterly direction across Trousdale County, destroying considerable property along a path 200 yards wide and 4 miles southeast of Hartsville. Several persons were injured. Both storms were probably tornadoes of a mild character.

Average accumulated departures for March, 1917.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	° F.	° F.	° F.	In.	In.	In.	0-10		P. ct.	
New England	33.2	+0.3	− 3.0	3.96	+0.20	−1.20	5.6	−0.1	74	− 1
Middle Atlantic	41.0	+0.9	+ 0.8	4.46	+0.80	−0.70	5.6	−0.1	71	− 2
South Atlantic	55.1	+1.1	+ 6.0	3.81	−0.50	−2.80	5.0	+0.1	73	− 2
Florida Peninsula	72.3	+2.1	+ 5.4	2.68	−0.10	−3.90	3.8	+0.1	74	− 4
East Gulf	59.3	+2.1	+ 8.4	6.59	+0.80	+1.50	5.3	+0.2	71	− 4
West Gulf	59.0	+1.2	+ 7.6	1.72	−1.40	−4.30	5.5	+0.4	67	− 5
Ohio Valley and Tennessee	45.0	+1.1	+ 0.7	6.35	+1.90	+2.00	5.7	−0.4	69	− 3
Lower Lakes	34.9	+1.9	− 4.0	2.69	+0.10	−1.00	6.3	−0.2	73	− 3
Upper Lakes	29.4	+1.8	− 9.1	2.44	+0.20	−1.40	6.2	+0.2	78	0
North Dakota	23.1	+2.5	− 7.1	0.44	−0.50	−0.40	5.1	−0.4	82	+ 4
Upper Mississippi Valley	38.0	+2.0	− 4.4	2.66	+0.30	−1.10	5.8	+0.1	70	− 4
Missouri Valley	37.8	+1.7	+ 2.2	1.90	0.00	−0.80	4.8	−0.7	68	− 2
Northern slope	25.3	−5.6	− 9.4	0.92	−0.20	−0.10	5.1	−0.3	69	+ 1
Middle slope	41.8	−0.7	+ 3.5	0.85	−0.60	−1.40	3.6	−1.1	55	− 6
Southern slope	53.4	+0.2	+ 5.5	0.22	−0.70	−1.50	2.9	−1.4	38	−16
Southern Plateau	46.4	−4.5	− 8.6	0.17	−0.40	−0.60	1.5	−2.2	37	− 4
Middle Plateau	33.7	−7.2	−23.2	0.83	−0.40	−1.10	4.3	−0.7	54	− 4
Northern Plateau	32.7	−7.5	−12.9	0.97	−0.60	−1.30	7.0	+1.2	68	+ 2
North Pacific	41.1	−3.5	− 5.7	4.64	0.00	−4.10	5.2	−1.4	81	+ 2
Middle Pacific	47.9	−3.5	− 7.0	1.77	−2.40	−4.20	3.3	−2.0	66	− 9
South Pacific	54.0	−1.7	− 3.4	0.36	−2.20	−1.30	2.2	−2.4	62	− 9

WEATHER CONDITIONS OVER THE NORTH ATLANTIC OCEAN DURING MARCH, 1916.

The data presented are for March, 1916, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month. Chart IX (XLV–27) shows for March, 1916, the averages of pressure, temperature, and prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich mean noon), together with notes on the locations and courses of the more severe storms of the month.

PRESSURE.

The distribution of the average monthly pressure as shown on Chart IX differed from the normal in several respects. The Azores, or North Atlantic HIGH, with a crest of 30.05 inches, was somewhat south of its usual position and slightly below the normal in intensity. One of the most unusual features was a HIGH, surrounded by the isobar of 30.00 inches, central near the south coast of Iceland, where the normal pressure is about 29.5 inches. A third HIGH, with a crest of 30.1 inches, and of limited area, covered a portion of southern Florida. A LOW of 29.7 inches was central near St. Johns, N. F., and there was a second LOW of similar intensity off the coast of Europe, extending as far west as the 12th meridian. South of the 50th parallel and east of the 55th meridian, the average pressure for the month was considerably lower than usual, while over the western division, it was not far from the normal.

The pressure changes from day to day were marked, showing the usual variable charactersitics common in March. The average pressure for the three decades of the month varied considerably over different portions of the ocean. In some mid-ocean regions the average for the last decade was considerably below that of the monthly, while in the waters adjacent to the American coast there was but little difference in the averages of the three decades, although the daily fluctuations were considerable. In the 5-degree square that includes the Faroe Islands the average for the first decade was 30.11 inches, the second 30.09 inches, and the last 11 days, 29.53 inches; the highest reading being 30.37 inches, on the 7th, and the lowest 28.72, inches on the 25th. In southern European waters, the pressure for the last decade was greater than for the first two, as in the square between latitude 35°–40°, longitude 5°–10° west, the average pressure for the first decade was 29.76 inches, the second, 29.68 inches, and the last 11 days 30.02 inches, the monthly mean being 29.82 inches. The extreme range for the month was, as usual, not so great as in northern waters, the highest reading being 30.43 inches, on the 30th, and the lowest, 29.20 inches, on the 10th. In the square between latitude 45°–50°, longitude 35°–40°, there was comparatively little difference in the pressure averages for the three decades of the month, as they were, 29.77 inches for the first, 29.80 inches for the second, and 29.73 inches for the last 11 days; the lowest reading was 29.26 inches on the 31st, and the highest, 30.21 inches on the 18th. In the square adjacent to the American coast, between the 40th and 45th parallels, there was also but little variation in the averages, and the extreme range was also comparatively small, the lowest reading being 29.20 inches on the 4th, and the highest, 30.10 inches, on the 31st. In the square that includes the Bermudas, the averages were as follows: First decade, 30.07 inches; second decade, 30.01 inches; last 11 days, 29.85 inches; the lowest reading was 29.60 inches, on the 4th, and the highest, 30.22 inches, on the 6th. In the Gulf of Mexico, the variation was somewhat greater than usual, as shown by the figures for the square between latitude 25°–30° and longitude 90°–95°, which are as follows: Average for the first decade, 30.04 inches; second decade, 30.17 inches; and last 11 days, 29.96 inches. The lowest reading was 29.78 inches, on the 25th, and the highest 30.40 inches, on the 16th.

GALES.

Weather conditions over the North Atlantic in March are usually uncertain and changeable, and March, 1916, was no exception to the general rule. Over the northern steamer routes, the number of gales, for the most part, was considerably below the normal, while in the limited territory between the 35th and 40th parallels, and the 50th and 70th meridians, the conditions were reversed, this region being visited by an exceptionally large number of gales during the month. The largest number was reported from the 5-degree square between latitude 35°–40° and longitude 60°–65°, where they occurred on 13 days, a percentage of 42, while the normal percentage is 21. Along the American coast the number of days on which gales were reported was near the normal, while in European waters they were less frequent than usual. In the region directly north of the Bermudas, where the heaviest weather prevailed, the gales occurred in all periods of the month, although there were not quite as many in the middle as in the first and last decades.

On Chart III, Tracks of Centers of Low Areas, March, 1916 (XLIV–27), a LOW (I on Chart IX) is shown on the morning of February 29, central near Salt Lake City, Utah. On the morning of March 2 this disturbance was near Norfolk, Va., but it was of slight intensity, and only light to moderate winds prevailed along the American coast. On the same day a second LOW existed in the vicinity of St. Johns, N. F., although it was impossible to determine its northern limits on account of lack of observations. Westerly gales of about 50 miles an hour were reported by a number of vessels between the 45th and 50th parallels, and the 40th and 50th meridians, while heavy snow occurred 5 degrees south of the storm area. The first LOW (I on Chart IX) moved rapidly during the next 24 hours, and on the 3d the center was near latitude 43°, longitude 55°. It was now well developed; the barometer had fallen to 29.35 inches, while strong gales, attended by snow, were prevalent over a limited area. The path of this disturbance then curved slightly toward the north, and continuing in its rapid rate of movement it reached, on March 4, a point near latitude 50°, longitude 35°. The lowest barometer reading was 29.23 inches, and two vessels reported gales of 55 and 64 miles an hour, respectively. This LOW proceeded in an easterly direction, and on the 5th was near latitude 50°, longitude 22°; the barometer had risen to 29.63 inches, and light to moderate winds prevailed within the area of low pressure. On March 3, a LOW (II on Chart IX) was central near Wilmington, N. C., where the barometer reading was 29.70 inches. The storm was of slight intensity, but snow occurred off the Virginia coast. The disturbance increased in force, and by the 4th the storm area extended from the 35th to the 44th parallels, and the 55th to 70th meridians, where gales of from 40 to 75 miles an hour prevailed, attended by snow and hail, the lowest barometer reading being 28.63 inches. The disturbance then curved sharply toward the northeast, and on the 5th the apparent center was over western Newfoundland, although it was impossible to locate it accurately on account of lack of observations. The barometer had risen slightly, and the storm area now extended as far east as the 45th meridian, although the winds were not

as violent as on the day before, the maximum velocity being 55 miles an hour. It then moved slowly toward the east, decreasing in intensity and increasing in extent, and the center on the 6th was in the vicinity of St. John's, N. F. The area of heavy winds was considerably less than on the 5th, although west and northwest gales, with hail and snow, were reported from a few vessels between the 35th and 42d parallels, and the 50th and 61st meridians. The disturbance then increased rapidly in its rate of movement, and on the 7th the center was near latitude 47°, longitude 38°. Three vessels, about, 5 degrees west of the center, encountered moderate northwest gales, accompanied by hail, and a few isolated reports of heavy winds were also received from the southern quadrants. On the 8th it was central near latitude 45°, longitude 27°, where the conditions of wind and weather had moderated considerably since the previous day. By the 9th, the center was near latitude 42°, longitude 16°, but the storm area had expanded considerably, as three vessels in the vicinity of the Azores encountered moderate to strong gales. The disturbance then decreased in its rate of translation, and increased in intensity, and on the 10th the center was about 4 degrees west of Vigo, Spain, the lowest barometric reading being 28.85 inches. Moderate to strong gales were interspersed with winds of less velocity throughout a large territory between the 35th and 50th parallels, and the 25th meridian and the European coast. The disturbance continued in its easterly movement, losing somewhat in intensity, and on the 11th it was over central Spain. A few vessels between the 35th and 50th parallels, east of the 20th meridian, encountered moderate northeasterly to northwesterly gales, although as a whole the winds were not as violent as on the day before. From the 12th to the 14th the storm moved but little, as its center during that period remained between the 45th and 50th parallels, and the 15th meridian, West longitude, and that of Greenwich. Only light to moderate winds prevailed in that territory, although on the 14th moderate northwest gales were reported from the vicinity of the Azores.

On Chart III, for March, 1916, referred to previously, a LOW (III on Chart IX) is shown on the evening of March 10, near Edmonton, Alberta. This moved across the country with a fairly uniform rate of translation, and on the morning of the 13th, the center was near Portland, Me. Light to moderate winds prevailed along the American coast, while snow was reported north of the 40th parallel, and west of the 55th meridian. This disturbance moved very rapidly during the next 24 hours, and on the 14th the center was near latitude 43°, longitude 52°, and moderate to strong gales prevailed over a small area in the southerly quadrants. From the 14th to the 17th its movement was somewhat reduced, curving to the south on the 15th and recurving toward the north by the 17th, so that it was practically on the same parallel of latitude on the 15th and 17th, while on the 16th it had moved considerably to the south, the center being only about 3 degrees north of the Azores. The area of low pressure was well defined during this period, but no winds of high velocity were reported until the 18th, when a number of vessels about 300 miles northwest of the center, which was near latitude 46° and longitude 14°, encountered northeasterly gales of from 40 to 65 miles an hour. On the 19th it curved slightly toward the northeast, and proceeded with a diminished rate of movement and energy, until the 21st, when it was central near the English Channel. This track was remarkable for its great length, although the path of the LOW was not accompanied by any unusual conditions of wind and weather.

On the 22d a LOW of limited dimensions was central near Washington, D. C., accompanied by light to moderate winds with some snow. This disturbance moved in a northeasterly direction, and on the 23d the center was about 100 miles southeast of Halifax, where the barometric reading was 28.92 inches. Moderate to strong gales covered an extensive area between the center and the 35th parallel, extending as far east as the 55th meridian. By the 24th the center was near the coast of Newfoundland, with a minimum barometric reading of 29.18 inches, and light to moderate winds. At the same time a HIGH with a crest of 30.20 inches was central near Washington, D. C., and a storm area existed between the 35th and 40th parallels, and the 55th and 60th meridians. From the 25th to the 29th the disturbance moved in an irregular manner over the region between the 35th and 50th parallels, and the 40th meridian and the American coast. On the 27th it reached its greatest intensity and northerly and northwesterly winds of from 40 to 65 miles an hour prevailed over a small area between the 35th and 42d parallels, and the 55th and 65th meridians. On the 28th a few reports were received showing gales, but the storm area was greatly contracted since the previous day. From the 28th until the end of the month this LOW moved slowly in a northeasterly direction, gradually diminishing in intensity.

TEMPERATURE.

The average temperature of the air over the ocean, was as a whole, somewhat below the normal north of the 40th parallel, while south of that line and in the northern part of the Gulf of Mexico, the departures were for the most part, slightly positive, although in the waters adjacent to the American and south Gulf coasts, the temperature was lower than usual. In northern waters the seasonal change in temperature was not so marked as usual, as the thermometer readings for the first part of the month differed but slightly from those taken during the last decade, and in some cases the latter readings were lower than the former.

The temperature departures at a number of Canadian and U. S. Weather Bureau Stations on the Atlantic and Gulf coasts were as follows:

	°F.		°F.
St. Johns, N. F.	−2.3	Norfolk, Va.	−3.6
Sydney, C. B. I.	−2.6	Hatteras, N. C.	−3.0
Halifax, N. S.	−3.3	Charleston, S. C.	−2.0
Eastport, Me.	−4.3	Key West, Fla.	−2.6
Portland, Me.	−5.2	Tampa, Fla.	−2.8
Boston, Mass.	−4.4	New Orleans, La.	+1.8
Nantucket, Mass.	−6.4	Galveston, Tex.	+3.5
Block Island, R. I.	−5.5	Corpus Christi, Tex.	+4.4
New York, N. Y.	−5.3		

FOG.

There was comparatively little fog during the month under discussion, the greatest amount occurring in the 5-degree square between latitude 35°–40° and longitude 45°–50°, where it was observed on 5 days, a percentage of 16, which was considerably below the normal for that region. No fog was reported east of the 30th meridian, while along the American coast it was reported on from 1 to 3 days.

SNOW AND HAIL.

The most frequent occurrence of snow was in the 5-degree square between latitude 40°–45°, longitude 55°–60°, where it was reported on 11 days. Over the waters adjacent to the American coast between the 35th and 45th parallels, snow was observed on from 5 to 6 days, while in mid-ocean, in the vicinity of the steamer lines it was not recorded on more than one day, in any 5-degree square.

There was little hail reported during the month, and in only one square did it occur on more than one day.

Winds of 50 miles per hour (22.4 m./sec.) or over, during March, 1917.

Station.	Date.	Wind.	
		Velocity.	Direction.
		Mis./hr.	
Bismarck, N. Dak.	24	51	nw.
Block Island, R. I.	4	53	ne.
Do.	5	58	nw.
Do.	6	52	nw.
Do.	19	50	nw.
Buffalo, N. Y.	8	56	sw.
Do.	14	58	sw.
Do.	15	50	w.
Do.	17	76	sw.
Do.	18	62	w.
Do.	20	52	sw.
Do.	23	64	sw.
Do.	24	60	sw.
Do.	27	64	sw.
Do.	28	56	sw.
Do.	29	64	sw.
Do.	31	58	w.
Burlington, Vt.	17	64	s.
Do.	23	54	s.
Do.	27	53	s.
Canton, N. Y.	24	60	sw.
Do.	27	57	sw.
Cheyenne, Wyo.	5	54	w.
Do.	6	52	w.
Do.	7	54	w.
Do.	23	64	w.
Do.	24	50	w.
Do.	25	56	w.
Cleveland, Ohio.	23	50	s.
Do.	28	54	w.
Columbus, Ohio.	17	53	w.
Detroit, Mich.	17	53	sw.
Do.	28	54	w.
Duluth, Minn.	14	51	w.
Do.	17	54	nw.
Do.	18	56	nw.
Eastport, Me.	5	64	e.

Station.	Date.	Wind.	
		Velocity.	Direction.
		Mis./hr.	
Eastport, Me.	6	50	n.
Do.	28	55	se.
El Paso, Tex.	31	54	nw.
Erie, Pa.	14	56	se.
Do.	16	50	se.
Do.	17	60	se.
Do.	23	66	sw.
Do.	28	56	sw.
Do.	31	55	sw.
Hatteras, N. C.	18	50	nw.
Indianapolis, Ind.	23	54	w.
Lexington, Ky.	31	52	sw.
Lincoln, Nebr.	16	54	nw.
Louisville, Ky.	23	52	w.
Do.	31	50	s.
Modena, Utah.	5	54	w.
Do.	9	58	sw.
Mount Tamalpais, Cal.	2	50	ne.
Do.	7	55	nw.
Do.	8	59	w.
Do.	9	61	nw.
Do.	10	52	nw.
Do.	14	56	nw.
Do.	20	65	nw.
Do.	21	64	nw.
Do.	22	55	nw.
Do.	24	62	nw.
Do.	25	69	nw.
Do.	29	50	w.
Do.	30	55	nw.
Do.	31	55	nw.
Nantucket, Mass.	5	60	e.
New York, N. Y.	12	58	nw.
Do.	17	52	nw.
Do.	18	63	nw.
Do.	19	72	nw.

Station.	Date.	Wind.	
		Velocity.	Direction.
		Mis./hr.	
New York, N. Y.	24	60	nw.
Do.	27	63	nw.
Do.	28	51	w.
Do.	29	53	nw.
North Head, Wash.	3	54	se.
Do.	4	62	s.
Do.	5	64	nw.
Do.	12	66	se.
Do.	20	62	s.
Do.	21	50	w.
Do.	23	64	s.
Do.	25	56	nw.
Do.	28	74	se.
Pocatello, Idaho.	30	50	sw.
Point Reyes Light, Cal.	5	65	nw.
Do.	7	52	nw.
Do.	8	65	sw.
Do.	9	61	nw.
Do.	10	56	nw.
Do.	11	60	nw.
Do.	18	65	nw.
Do.	19	70	nw.
Do.	20	61	nw.
Do.	21	73	nw.
Do.	22	57	nw.
Do.	24	50	nw.
Do.	30	61	nw.
Do.	31	58	nw.
Port Huron, Mich.	23	50	w.
Portland, Me.	5	60	nw.
Do.	12	56	nw.
Do.	13	50	nw.
Do.	19	54	nw.
Do.	27	62	se.
Do.	28	69	se.
Providence, R. I.	27	50	s.

Station.	Date.	Wind.	
		Velocity.	Direction.
		Mis./hr.	
Rapid City, S. Dak.	30	60	n.
St. Louis, Mo.	7	51	sw.
Do.	10	52	sw.
Do.	16	51	w.
Salt Lake City, Utah.	9	60	w.
Sandusky, Ohio.	17	52	sw.
Sandy Hook, N. J.	5	53	sw.
Do.	17	51	s.
Do.	23	52	s.
Do.	24	52	s.
Do.	27	56	s.
Do.	29	51	s.
Sioux City, Iowa.	16	56	nw.
Do.	30	50	n.
Syracuse, N. Y.	17	55	s.
Do.	23	60	s.
Do.	29	56	sw.
Tatoosh Island, Wash.	4	60	w.
Do.	23	70	sw.
Do.	28	64	s.
Toledo, Ohio.	7	51	sw.
Do.	10	52	s.
Do.	14	50	sw.
Do.	17	60	sw.
Do.	23	53	w.
Do.	28	54	sw.
Do.	31	50	w.
Wichita, Kans.	6	60	w.
Do.	7	50	nw.
Do.	9	50	s.
Do.	16	52	nw.
Do.	22	52	sw.

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by section, March, 1917.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	57.3	+ 0.2	Centerville	89	12	Florence	14	5†	9.44	+3.85	Bridgeport	17.59	Robertsdale	1.66
Arizona	48.2	− 4.3	Mohawk	97	31	Fort Valley	−10	16	0.15	−0.87	Cosnino	1.00	18 stations	0.00
Arkansas	53.0	0.0	Camden	87	26	Osceola	9	5	5.32	+0.41	Alicia	12.18	Ozark	0.56
California	45.7	− 6.1	Wasco	100	31	Alturas	−29	2	1.58	−3.16	Crescent City	11.35	11 stations	0.00
Colorado	28.4	− 6.6	Holly	86	30	Dillon	−36	4	1.06	−0.25	Savage Basin	4.10	5 stations	T.
Florida	68.2	+ 2.3	Fort Meade	93	26	Garniers (near)	24	6	1.99	−1.15	Federal Point	5.91	2 stations	0.19
Georgia	57.3	+ 1.0	4 stations	89	13†	Blue Ridge	13	6	7.86	+2.92	Blue Ridge	17.06	Bainbridge	1.81
Hawaii (February)	68.5	− 0.2	Mahukona	94	23	Glenwood	43	1	4.01	−2.05	Olokele Ditch	11.45	Insane Asylum	1.81
Idaho	25.8	− 9.8	Deer Flat	74	29	Stanley	−34	1	2.15	−0.05	Oxford Ranger Sta.	11.38	Lewiston	0.45
Illinois	42.0	+ 2.3	Lincoln	84	31	6 stations	0	5	2.85	−0.16	Bement	5.87	Antioch	1.06
Indiana	41.3	+ 1.2	Huntingburg	84	23	Richmond	0	5	3.83	+0.05	Jeffersonville	7.13	Auburn	1.01
Iowa	34.6	+ 1.3	Lenox	85	31	Lake Park	−13	4	1.84	+0.07	Sanborn	4.35	Audubon	0.57
Kansas	43.8	+ 1.0	Alton	94	30	Tribune	− 6	4	0.98	−0.44	Chanute	4.30	Lakin	T.
Kentucky	45.9	− 0.4	Beattyville	84	31	Mount Sterling	0	6	6.53	+1.64	Middlesboro	13.39	Owensboro	2.63
Louisiana	61.8	+ 0.5	Amite	90	26	Kelly (near)	18	5	3.60	−1.04	Dutchtown	7.05	Burrwood	.44
Maryland-Delaware	41.2	− 1.2	6 stations	82	31	Oakland, Md	− 5	7	5.46	+1.78	Millsboro, Del	8.85	Western Port, Md	2.87
Michigan	29.8	+ 0.6	Cassopolis	73	31	Humboldt	−41	5	2.03	+0.05	Ironwood	4.84	Hart	0.42
Minnesota	24.7	−0.08	2 stations	67	30	2 stations	−43	4	1.68	+0.56	Duluth	4.97	Ada	0.05
Mississippi	57.7	+ 0.3	2 stations	88	25†	Boonville	10	5	6.88	+1.44	Holly Springs	11.92	Pascagonla	2.08
Missouri	45.2	+ 1.7	Bethany (2)	86	30†	Lamonte	− 7	5	2.91	−0.42	Cassville	6.22	Hermann	0.74
Montana	22.7	− 6.8	Billings	67	29	2 stations	−38	3	0.91	−0.09	Trout Creek	4.78	2 stations	T.
Nebraska	33.8	− 1.3	Alma	93	30	Butte	−12	4	1.25	+0.12	Oshkosh	2.86	Holdredge	0.32
Nevada	33.3	− 6.5	Mina	89	29	Owyhee	−14	12	0.47	−0.51	Marlette Lake	2.06	3 stations	0.00
New England	31.3	+ 0.8	Orono, Me	65	12	2 stations	−18	7, 20	3.71	−0.01	Bridgeport, Conn	6.49	Enosburg Falls, Vt.	1.13
New Jersey	38.2	+ 0.3	2 stations	72	31	Layton	0	7	4.65	+0.58	Northfield	7.14	Newton	2.28
New Mexico	40.4	− 4.3	Artesia	92	29	Fort Union	−23	4	0.22	−0.55	Aspen Grove Ranch.	2.27	22 stations	0.00
New York	32.1	+ 0.1	Canisius College	73	26	North Lake	−11	20	2.99	−0.29	Farmingdale	7.49	Avon	0.77
North Carolina	49.3	− 0.9	Wilson	83	31	Banners Elk	7	6	6.68	+2.08	Andrews	19.39	Hatteras	2.39
North Dakota	22.2	− 0.4	Marstonmoor	67	30	Eckman	−39	4	0.40	−0.43	Ashley	1.50	2 stations	0.00
Ohio	39.6	+ 0.5	Ironton	84	31	Milligan	− 9	6	3.65	+0.07	Syracuse	7.10	Prospect	1.60
Oklahoma	51.4	− 0.6	2 stations	94	10†	2 stations	0	4	0.97	−1.01	Webbers Fall	4.72	3 stations	T.
Oregon	36.4	− 6.4	Vale	74	29	Crescent	−27	1	3.87	+0.84	Golden Falls	17.68	Ana River	0.10
Pennsylvania	37.3	− 0.2	Huntingdon	84	31	2 stations	−12	6	3.68	+0.04	Friends' Asylum	6.06	Brookville	1.43
Porto Rico	73.3	− 0.5	Maricao	92	25	Aibonito	48	30	1.63	−1.93	Rio Grande (El Verde)	5.11	Isodora	0.00
South Carolina	55.0	+ 0.4	St. Matthews	88	12	Mountain Rest	14	6	5.39	+1.48	Mountain Rest	12.42	Columbia	2.54
South Dakota	26.6	− 3.5	Vivian	89	30	McIntosh	−33	4	1.39	+0.63	Marion	5.78	Interior	0.21
Tennessee	49.6	+ 0.1	2 stations	83	31	Wildersville	− 2	5	10.17	+4.69	Sevierville	15.05	Kenton	4.59
Texas	59.5	0.0	Encinal	100	31	Lieb (near)	− 3	4	0.94	−1.10	Ringo Crossing	5.01	8 stations	0.00
Utah	29.2	− 9.0	St. George	85	29	East Portal	−37	2	0.96	−0.70	Pinecrest	6.80	4 stations	0.00
Virginia	44.9	− 0.3	Woodstock	84	31	Burkes Garden	5	6	6.29	+2.55	Elk Knob	12.08	Lincoln	2.03
Washington	36.2	− 5.6	2 stations	71	27†	2 stations	−11	1	3.68	+0.49	Yale	15.45	Kennewick	0.16
West Virginia	41.9	− 0.8	2 stations	85	31	Spencer	− 3	6	6.58	+2.25	Pickens	14.20	Morgantown	3.10
Wisconsin	27.8	− 0.7	Racine	74	31	Deerskin Dam	−46	5	2.21	+0.42	Vudesare	4.31	Lake Mills	0.73
Wyoming	20.7	− 9.4	Fort Laramie	74	30	Moran	−42	1	1.27	−0.12	Moran	5.70	Eden	0.00

† Other dates also.

DESCRIPTION OF CHARTS AND TABLES.

(See the REVIEW for January, 1917, p. 40.)

TABLE I.—*Climatological data for Weather Bureau Stations, March, 1917.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with .01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England.							33.2	+0.3										74	3.96	+0.2										5.6		
Eastport	76	67	85	29.90	29.99	+0.06	29.4	+0.5	46	28	36	5	20	23	25	27	22	74	2.95	−1.3	12	9,874	w.	64	e.	5	9	10	12	5.9	14.9	....
Greenville	1,070	6	....	28.78	29.99	......	25.0	......	52	26	35	−5	3	15	42	....	....	....	3.90	......	11						13	6	12	....	17.3	35.0
Portland, Me.	103	82	117	29.91	30.04	+ .08	32.1	+0.1	53	31	39	8	20	25	23	28	21	67	4.53	+0.8	14	13,003	nw.	69	se.	28	15	5	11	5.2	15.5	....
Concord	288	70	79	29.72	30.04	+ .04	31.8	+0.3	59	26	41	0	7	23	39	....	....	....	2.03	−1.4	13	5,169	nw.	31	nw.	19	14	5	12	4.9	12.0	....
Burlington	404	11	48	29.58	30.04	+ .04	28.5	+1.2	57	26	36	1	7	21	33	....	....	....	2.99	+1.2	12	10,564	s.	64	s.	17	10	9	12	5.8	20.5	....
Northfield	876	12	60	29.05	30.03	+ .03	26.0	−0.2	53	26	36	−10	7	16	44	24	20	77	2.20	−0.6	13	6,414	s.	39	s.	17	9	8	14	6.1	17.1	....
Boston	125	115	188	29.90	30.04	+ .07	37.2	+2.2	61	26	44	17	5	30	25	33	28	71	3.73	−0.4	13	9,265	w.	45	ne.	5	12	10	9	5.0	12.9	....
Nantucket	12	14	90	30.02	30.03	+ .05	35.2	−1.6	48	31	41	21	20	29	19	33	30	82	5.85	+1.9	14	12,347	nw.	60	e.	5	13	6	12	6.1	13.6	....
Block Island	26	11	46	30.01	30.04	+ .06	35.9	0.0	49	27	40	21	19	31	23	33	30	81	4.85	+0.5	14	14,314	nw.	58	nw.	5	11	5	15	6.1	9.5	....
Narragansett Pier	....	9	....	......	......	......	32.5	−2.5	48	29	37	14	7	28	20	....	....	....	5.83	......	14	......	nw.	....	......	....	13	6	12	....	15.5	....
Providence	160	215	251	29.86	30.04	+ .06	36.0	+0.3	55	31	43	16	20	29	27	32	27	71	4.14	−0.5	13	11,397	nw.	50	s.	27	9	12	10	5.5	9.6	....
Hartford	159	122	140	29.88	30.06	+ .07	36.2	+1.2	57	26	44	13	7	29	32	31	25	66	4.12	−0.2	14	6,690	nw.	34	sw.	28	10	9	12	5.7	7.2	....
New Haven	106	117	155	29.95	30.07	+ .08	37.4	+2.0	56	24	44	16	7	30	29	34	30	77	6.21	+1.8	16	7,164	nw.	40	nw.	19	10	10	11	5.5	9.3	....
Middle Atlantic States.							41.0	+0.9										71	4.46	+0.8										5.6		
Albany	97	102	115	29.95	30.06	+0.05	33.9	+1.8	59	26	42	9	7	26	29	30	24	70	3.14	+0.4	13	6,607	s.	35	s.	23	11	10	10	5.2	16.3	....
Binghamton	871	10	69	29.10	30.05	+ .03	33.8	+1.8	66	31	42	4	7	26	38	....	....	....	1.89	−0.8	14	5,600	nw.	29	nw.	27	6	9	16	7.0	11.4	....
New York	314	414	454	29.72	30.07	+ .07	38.7	+1.2	64	31	45	18	6	32	30	34	26	63	3.38	−0.7	13	15,444	nw.	72	nw.	19	9	7	15	6.2	11.4	....
Harrisburg	374	94	104	29.69	30.10	+ .07	39.4	+1.6	73	31	47	16	6	32	33	34	27	67	3.48	+0.4	14	6,271	nw.	32	w.	28	10	9	12	6.0	10.5	....
Philadelphia	117	123	190	29.98	30.11	+ .09	42.0	+2.0	69	31	50	22	6	34	28	38	35	81	5.46	+2.0	13	8,320	nw.	38	nw.	27	11	10	10	5.1	9.6	....
Reading	325	81	98	29.74	30.10	......	39.2	......	70	31	47	16	7	32	32	34	28	69	4.63	+1.1	15	6,442	nw.	31	w.	29	10	9	12	6.0	13.3	....
Scranton	805	111	119	29.19	30.07	+ .05	36.4	+1.5	65	31	44	15	6	29	33	32	27	72	2.99	−0.1	16	6,682	sw.	37	sw.	27	8	7	16	6.7	11.7	....
Atlantic City	52	37	48	30.04	30.10	+ .08	40.0	+1.2	62	12	46	22	6	34	30	36	32	76	6.93	+3.2	13	6,837	nw.	32	sw.	17	8	13	10	5.6	1.1	....
Cape May	18	13	49	30.10	30.12	+ .11	40.2	−0.6	58	12	46	24	6	34	23	37	....	....	6.96	+3.2	17	8,102	nw.	42	s.	27	10	11	10	5.3	2.4	....
Sandy Hook	22	10	57	30.05	30.07	......	37.8	......	60	31	43	20	6	32	28	35	32	79	3.54	......	12	13,169	w.	56	s.	27	10	9	12	5.5	9.8	....
Trenton	190	159	183	29.87	30.08	......	39.2	......	69	31	47	18	6	32	32	35	30	73	3.45	−0.6	12	10,078	w.	49	nw.	27	11	9	11	5.5	7.0	....
Baltimore	123	100	113	29.98	30.11	+ .08	43.2	+1.3	78	31	51	22	6	35	35	37	31	66	3.80	−0.1	13	6,119	sw.	39	sw.	29	10	11	10	5.5	1.5	....
Washington	112	62	85	29.98	30.11	+ .07	43.4	+1.2	82	31	52	23	6	34	43	37	31	66	5.12	+1.3	14	6,488	nw.	42	nw.	27	11	10	10	5.2	1.5	....
Lynchburg	681	153	188	29.35	30.11	+ .06	46.6	+1.2	79	31	57	22	6	36	37	40	33	66	4.97	+1.2	15	6,508	nw.	40	n.	18	12	9	10	5.4	0.1	....
Norfolk	91	170	205	30.03	30.13	+ .10	47.2	−0.5	75	31	56	29	19	39	29	42	37	73	4.60	+0.3	13	11,243	ne.	49	nw.	18	12	9	10	5.2	T.	....
Richmond	144	11	52	29.96	30.12	+ .08	46.6	−0.3	80	31	56	26	6	37	34	41	37	75	5.97	+2.2	16	7,464	ne.	39	nw.	27	12	8	11	5.0	T.	....
Wytheville	2,293	49	55	27.68	30.11	+ .06	42.6	+0.3	74	31	52	16	6	33	40	37	32	71	4.58	+0.1	16	6,968	w.	40	w.	17	15	6	10	4.5	T.	....
South Atlantic States.							55.1	+1.1										73	3.81	−0.5										5.0		
Asheville	2,255	70	84	27.73	30.13	+0.07	46.1	+0.2	74	31	55	17	6	37	32	40	33	67	5.76	+0.7	17	8,901	se.	34	nw.	29	12	7	12	5.2	0.6	....
Charlotte	773	153	161	29.28	30.13	+ .08	50.3	−0.5	75	31	59	26	6	42	28	44	39	71	6.42	+1.8	16	8,720	sw.	48	w.	18	12	8	11	5.1	0.0	....
Hatteras	11	12	50	30.02	30.13	+ .09	51.2	−0.2	65	31	57	34	6	45	25	47	44	81	2.39	−3.1	10	12,042	sw.	50	nw.	18	13	6	12	5.1	0.0	....
Manteo	12	5	43	......	......	......	49.6	......	74	31	60	28	7	40	....	....	....	....	3.46	−1.6	8	......	sw.	....	......	....	14	4	13	....	0.0	....
Raleigh	376	103	110	29.72	30.13	+ .08	49.2	−1.2	78	31	59	26	6	40	32	44	39	74	5.70	+1.4	14	7,151	nw.	37	nw.	18	12	4	15	5.7	0.0	....
Wilmington	78	81	91	30.06	30.15	+ .10	55.4	+1.7	79	12	65	31	6	46	30	49	44	72	4.00	+0.4	9	6,655	sw.	28	sw.	4	15	5	11	4.5	0.0	....
Charleston	48	11	92	30.10	30.15	+ .09	59.4	+2.2	84	12	67	34	6	52	28	53	49	76	3.05	−0.7	10	8,980	sw.	34	ne.	16	15	6	10	4.5	0.0	....
Columbia, S. C.	351	41	57	29.75	30.14	+ .08	55.2	+1.2	79	31	64	29	6	46	30	47	40	62	2.54	−1.2	11	6,372	ne.	34	sw.	17	12	6	13	5.2	0.0	....
Augusta	180	62	77	29.94	30.13	+ .07	56.9	+1.0	82	12	67	28	6	47	35	51	47	74	4.10	−0.8	9	5,064	se.	26	w.	17	12	7	12	5.3	0.0	....
Savannah	65	150	194	30.08	30.15	+ .09	61.5	+3.2	84	12	70	33	6	53	26	54	51	77	2.69	−1.0	8	10,124	sw.	46	nw.	5	11	6	14	5.5	0.0	....
Jacksonville	43	200	245	30.10	30.16	+ .10	65.6	+3.7	85	13	74	35	6	57	28	58	53	73	1.81	−1.7	6	9,522	sw.	42	sw.	4	14	12	5	3.8	0.0	....
Florida Peninsula.							72.3	+2.1										74	2.68	+0.1										3.8		
Key West	22	10	64	30.08	30.10	+0.05	75.2	+2.4	83	17	80	62	5	70	14	68	66	76	3.87	+2.4	9	8,741	se.	28	n.	5	16	11	4	3.7	0.0	....
Miami	25	71	79	30.12	30.15	......	72.4	+0.4	82	18	78	54	19	67	20	66	63	74	3.03	+0.3	7	7,200	e.	32	e.	7	14	11	6	4.3	0.0	....
Sand Key	23	39	72	30.06	30.09	+ .04	74.2	......	80	28	76	62	5	72	14	69	66	77	2.67	......	6	12,630	e.	40	n.	5	18	9	4	3.7	0.0	....
Tampa	35	79	96	30.11	30.15	+ .08	69.3	+3.4	85	12	79	40	6	60	31	60	56	71	0.47	−2.3	3	5,232	ne.	24	sw.	27	17	12	2	3.5	0.0	....
East Gulf States.							59.3	+2.1										71	6.59	+0.8										5.3		
Atlanta	1,174	190	216	28.89	30.14	+0.08	52.6	+0.2	79	12	62	20	5	43	36	46	39	66	9.15	+3.4	17	10,091	nw.	48	nw.	27	12	7	12	5.3	T.	....
Macon	370	78	87	29.74	30.14	+ .08	57.0	+2.2	82	13	68	27	6	46	38	50	44	68	6.21	+0.7	12	5,011	nw.	28	s.	4	12	7	12	5.0	0.0	....
Thomasville	273	49	58	29.85	30.15	+ .09	62.8	+2.6	83	13	74	30	5	51	40	54	49	69	1.98	−3.1	6	4,137	sw.	28	sw.	4	10	13	8	5.1	0.0	....
Pensacola	56	149	185	30.08	30.14	+ .08	62.2	+1.1	75	21	68	28	5	56	39	58	54	79	2.62	−2.7	9	10,989	s.	43	nw.	27	6	12	13	6.0	0.0	....
Anniston	741	9	57	29.35	30.15	+ .09	54.6	+2.1	80	12	66	21	5	43	38	....	....	....	12.49	+6.7	14	5,400	nw.	36	nw.	27	13	10	8	4.5	T.	....
Birmingham	700	11	48	29.37	30.15	+ .09	56.2	+1.0	81	12	67	20	5	46	30	48	40	63	11.85	+6.1	15	6,651	s.	31	w.	27	12	7	12	5.2	T.	....
Mobile	57	125	161	30.07	30.13	+ .07	63.4	+4.3	80	21	71	30	5	55	39	57	53	76	2.28	−4.9	6	8,634	s.	38	nw.	27	8	15	8	5.4	0.0	....
Montgomery	223	100	112	29.89	30.15	+ .09	60.2	+2.3	82	31	70	25	5	50	40	52	46	66	10.65	+4.3	15	5,691	se.	30	sw.	17	10	12	9	5.0	0.0	....
Corinth	469	6	....	......	......	......	51.1	......	81	12	63	14	5	39	42	....	....	....	9.58	......	15	......	s.	....	......	....	11	11	9	....	0.5	....
Jackson	304	5	....	......	......	......	60.2	......	86	26	71	22	5	49	38	....	....	....	4.76	......	15	......	s.	....	......	....	11	9	11	....	T.	....
Meridian	375	85	93	29.72	30.12	+ .07	58.8	+2.5	83	12	70	23	5	48	34	51	45	69	6.92	+1.3	14	4,926	s.	26	sw.	27	12	8	11	5.0	T.	....
Vicksburg	247	65	74	29.84	30.13	+ .09	58.5	+0.3	83	31	68	28	5	49	29	51	45	68	5.31	−0.9	13	6,631	se.	41	nw.	26	12	6	13	5.1	T.	....
New Orleans	51	76	84	30.05	30.11	+ .07	66.1	+4.1	83	26	74	36	5	58	30	60	58	82	3.03	−2.3	6	6,067	s.	29	nw.	27	7	9	15	6.4	0.0	....
West Gulf States.							59.0	+1.2										67	1.72	−1.4										5.5		
Shreveport	249	77	93	29.81	30.09	+0.07	58.4	+0.2	84	26	68	29	5	48	32	50	44	65	2.12	−2.4	9	7,404	s.	29	n.	4	10	5	16	6.0	0.5	....
Bentonville	1,303	11	44	28.65	30.03	+ .02	49.5	+2.2	80	31	61	16	5	38	35	....	....	....	2.38	−1.4	10	7,097	s.	34	s.	30	15	7	9	4.3	1.1	....
Fort Smith	457	79	94	29.55	30.03	+ .02	53.6	+2.3	81	29	65	24	5	43	37	46	38	61	1.18	−2.4	9	8,172	e.	45	w.	13	16	3	12	4.6	T.	....
Little Rock	357	139	147	29.70	30.08	+ .05	54.0	+1.3	81	26	63	24	5	45	29	48	42	69	6.43	+1.5	13	9,001	s.	39	n.	27	13	3	15	5.2	0.4	....
Brownsville	57	4	26	......	......	......	69.5	......	88	23	78	30	5	61	38	....	....	....	1.51	......	6	......	s.	....	......	....	....	....	....	....	0.0	....
Corpus Christi	20	69	77	30.03	30.05	+ .07	64.9	+0.5	79	26	70	39	4	60	21	60	57	81	0.14	−1.7	4	12,669	se.	48	s.	10	1	8	22	7.9	0.0	....
Dallas	512	109	117	29.51	30.06	......	57.8	......	85	30	69	27	4	47	38	....	....	....	3.40	......	8	9,485	s.	49	s.	6	12	8	11	5.0	1.2	....
Fort Worth	670	106	114	29.31	30.03	+ .05	58.3	+1.7	86	30	69	26	4	47	37	48	39	56	2.42	+0.7	6	10,660	s.	45	s.	6	14	6	11	4.6	1.0	....
Galveston	54	106	114	30.02	30.08	+ .07	63.3	+1.0	76	26	68	38	4	59	17	58	55	79	0.91	−2.0	8	10,496	se.	42	nw.	4	7	16	8	5.8	0.0	....
Houston	138	111	121	29.93	30.08	......	64.0	+0.5	83	31	72	31	5	56	24	....	....	....	0.65	......	5	8,366	se.	29	s.	31	7	9	15	6.5	0.0	....
Palestine	510	64	72	29.53	30.06	+ .06	59.4	+0.9	86	21	69	29	4	50	31	51	45	65	1.27	−2.2	9	7,822	s.	29	s.	6	11	3	17	5.8	0.1	....
San Antonio	701	119	132	29.30	30.03	+ .05	63.6	+1.5	89	26	74	29	4	53	38	53	43	57	0.16	−1.5	6	7,594	sw.	39	n.	4	11	14	6	4.6	0.0	....
Taylor	582	55	63	29.47	30.08	+ .09	60.4	+0.7	89	21	72	23	5	49	38	....	....	....	0.16	−2.5	7	9,822	s.	41	s.	10	9	9	13	5.8	T.	....

TABLE I.—*Climatological data for Weather Bureau Stations, March, 1917*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee.							**45.0**	**+1.1**										**69**	**6.35**	**+1.9**										**5.7**		
Chattanooga	762	189	213	29.32	30.14	+0.08	51.5	+0.2	78	31	60	20	5	42	29	44	38	67	13.91	+7.7	19	7,186	nw.	37	nw.	24	11	6	14	5.5	0.3	....
Knoxville	996	93	100	29.05	30.12	+ .06	48.9	+0.7	78	31	59	20	6	39	34	43	36	68	13.35	+7.8	20	4,438	ne.	24	w.	18	11	9	11	5.4	0.2	....
Memphis	399	76	97	29.70	30.13	+ .09	53.5	+1.4	80	31	61	19	5	46	24	46	40	65	7.51	+1.7	12	8,632	s.	42	nw.	27	13	4	14	5.1	2.9	....
Nashville	546	168	191	29.53	30.13	+ .08	49.9	+0.7	79	31	59	14	5	41	33	43	37	68	8.06	+2.6	17	9,638	se.	38	nw.	27	13	6	12	5.1	8.0	....
Lexington	989	193	230	29.02	30.11	+ .06	44.2	+0.8	78	31	53	15	6	35	27	....	....	....	5.48	+0.8	16	13,479	sw.	52	sw.	31	13	7	11	5.0	15.9	....
Louisville	525	219	255	29.52	30.11	+ .06	46.4	+1.1	78	31	56	16	6	37	28	39	31	63	6.30	+2.0	13	13,024	s.	52	w.	23	10	8	13	5.6	7.5	....
Evansville	431	139	175	29.61	30.09	+ .05	47.2	+2.6	76	31	56	18	5	38	30	41	36	71	3.03	−1.6	14	12,291	s.	42	s.	7	9	12	10	5.1	8.2	....
Indianapolis	822	194	230	29.16	30.06	+ .02	41.6	+2.0	75	31	51	14	5	32	39	36	30	68	4.75	+0.7	13	12,912	s.	54	w.	23	9	5	17	6.5	3.0	....
Terre Haute	575	96	129	29.42	30.05	.....	43.2	.....	75	31	52	13	5	34	36	37	30	67	3.79	.....	12	11,454	sw.	40	sw.	17	6	14	11	6.4	0.8	....
Cincinnati	628	11	51	29.39	30.09	+ .04	43.0	+2.2	79	31	52	14	6	34	33	36	30	67	4.06	+0.4	14	9,335	sw.	39	sw.	17	12	4	15	5.7	6.0	....
Columbus	824	173	222	29.18	30.07	+ .03	40.4	+1.2	78	31	49	12	6	32	30	36	31	72	3.59	+0.4	14	11,377	sw.	53	w.	17	9	10	12	5.5	4.2	....
Dayton	899	181	216	29.08	30.05	.....	41.3	+1.0	77	31	50	13	6	32	28	37	33	76	3.95	+0.5	14	12,166	sw.	43	nw.	27	9	8	14	6.2	6.1	....
Pittsburgh	842	353	410	29.15	30.07	+ .03	40.6	+1.1	75	31	49	12	6	32	34	35	29	70	3.36	+0.4	15	11,389	w.	48	w.	27	8	10	13	6.1	13.1	....
Elkins	1,940	41	50	27.99	30.10	+ .05	40.0	+0.9	78	31	51	12	6	29	46	34	29	72	7.12	+3.0	20	4,562	w.	30	w.	27	10	4	17	6.4	8.5	....
Parkersburg	638	77	84	29.43	30.10	+ .05	42.2	−0.1	80	31	52	7	6	33	35	37	32	71	4.46	+0.6	16	6,084	se.	34	nw.	27	14	4	13	5.5	13.9	....
Lower Lake Region.							**34.9**	**+1.9**										**73**	**2.69**	**+0.1**										**6.3**		
Buffalo	767	247	280	29.15	30.01	−0.01	33.2	+2.0	66	26	40	6	6	26	30	30	27	79	2.69	+0.1	18	17,165	sw.	76	sw.	17	7	10	14	6.4	13.5	....
Canton	448	10	61	29.51	30.00	.....	28.4	+0.7	64	26	36	2	19	20	27	....	....	....	1.98	−0.9	14	11,458	sw.	60	sw.	24	15	5	11	4.7	11.7	T.
Oswego	335	76	91	29.64	30.03	+ .02	32.0	+0.6	65	26	38	10	19	26	28	29	26	78	2.02	−0.8	17	10,414	nw.	34	w.	18	6	8	17	6.7	9.1	....
Rochester	523	97	113	29.44	30.03	+ .01	34.0	+2.7	70	26	41	9	6	27	32	30	24	68	2.96	0.0	19	8,701	w.	40	sw.	24	7	6	18	6.9	14.6	....
Syracuse	597	97	113	29.38	30.04	+ .02	32.8	+1.4	64	31	40	9	19	26	33	29	24	71	2.42	0.0	18	11,659	w.	60	s.	23	4	14	13	6.6	12.4	....
Erie	714	130	166	29.23	30.02	.00	36.0	+2.9	70	26	44	8	6	28	26	33	28	75	3.13	+0.5	17	15,004	sw.	66	sw.	23	7	8	16	6.5	10.3	....
Cleveland	762	190	201	29.20	30.04	+ .01	37.3	+3.1	70	26	44	11	6	30	30	33	28	69	2.14	−0.6	16	13,901	w.	54	w.	28	6	10	15	6.6	6.1	....
Sandusky	629	62	103	29.33	30.03	.00	37.8	+2.6	71	26	46	9	6	30	31	33	28	72	2.72	+0.2	13	13,264	sw.	52	sw.	17	7	7	17	6.7	7.7	....
Toledo	628	208	243	29.33	30.03	.00	37.8	+3.0	70	26	46	9	6	29	26	33	28	70	4.25	+2.0	15	14,526	sw.	60	sw.	17	10	7	14	6.0	7.8	....
Fort Wayne	856	113	124	29.10	30.05	.....	38.0	−0.9	71	26	47	12	5	29	34	34	29	74	3.71	.....	13	10,416	sw.	48	sw.	17	6	7	18	6.7	0.9	....
Detroit	730	218	245	29.20	30.01	− .02	36.2	+3.3	68	26	44	11	6	28	25	31	27	72	2.61	+0.2	15	11,615	w.	54	w.	28	7	12	12	6.0	3.1	....
Upper Lake Region.							**29.4**	**+1.8**										**78**	**2.44**	**+0.2**										**6.2**		
Alpena	609	13	92	29.28	29.97	−0.06	27.0	+2.0	61	31	34	− 4	4	20	31	24	21	81	1.56	−0.5	12	11,192	nw.	48	e.	14	8	11	12	5.5	6.8	T.
Escanaba	612	54	60	29.28	29.97	− .07	24.2	+0.7	43	24	32	−20	5	16	35	23	20	83	2.80	+0.8	12	7,615	n.	34	n.	17	9	10	12	5.9	22.8	T.
Grand Haven	632	54	92	29.29	29.99	− .04	33.0	+2.2	62	22	40	4	4	26	33	29	25	76	1.24	−1.3	12	11,121	w.	46	w.	17	10	8	13	5.7	1.7	....
Grand Rapids	707	70	87	29.21	30.00	− .03	35.0	+2.0	71	31	43	6	4	27	29	31	26	74	1.87	−0.6	13	6,963	w.	32	w.	17	7	13	11	6.0	3.2	....
Houghton	684	62	99	29.21	29.96	− .08	22.8	−1.0	45	25	32	−22	5	14	42	....	....	....	4.14	+2.0	16	8,646	e.	44	ne.	14	9	9	13	6.1	32.3	6.0
Lansing	878	11	62	29.03	29.99	.....	34.6	+3.3	68	26	43	9	4	26	33	30	26	75	2.88	+0.6	13	7,169	sw.	34	nw.	28	6	11	14	6.7	3.6	....
Ludington	637	60	66	29.26	29.98	.....	30.7	.....	55	22	38	− 2	5	24	28	28	25	81	1.79	.....	12	9,567	w.	43	w.	14	8	10	13	6.1	3.2	....
Marquette	734	77	111	29.16	29.99	− .05	25.3	+1.6	52	22	32	−10	5	18	32	22	19	81	2.97	+0.9	16	8,049	nw.	43	e.	13	4	10	17	7.1	30.5	6.8
Port Huron	638	70	120	29.28	29.99	− .04	33.6	+4.0	67	26	41	6	6	26	29	30	26	77	1.67	−0.8	14	11,457	sw.	50	w.	23	8	8	15	6.2	5.0	....
Saginaw	641	48	82	29.27	29.98	.....	33.8	.....	66	26	42	8	4	26	29	30	27	81	1.43	−1.2	10	9,938	w.	48	w.	28	4	8	19	7.5	1.3	....
Sault Sainte Marie	614	11	61	29.26	29.98	− .05	21.2	−0.1	44	25	31	−19	5	12	41	20	16	82	2.48	+0.6	13	8,764	nw.	49	nw.	29	9	9	13	6.1	20.0	6.0
Chicago	823	140	310	29.10	30.01	− .02	38.8	+4.4	76	31	46	11	5	31	31	33	27	64	2.11	−0.4	9	11,921	sw.	44	w.	14	7	12	12	5.8	2.1	....
Green Bay	617	109	144	29.27	29.96	− .08	29.0	+2.2	51	22	36	−16	5	22	32	26	22	75	2.45	0.0	9	9,783	s.	44	sw.	14	5	13	13	6.7	4.5	....
Milwaukee	681	119	133	29.22	29.98	− .05	34.4	+3.5	71	31	41	4	5	27	34	31	28	82	1.53	−1.1	9	9,719	w.	45	se.	16	8	11	12	5.9	4.7	....
Duluth	1,133	11	47	28.72	29.99	− .07	23.2	−0.9	46	31	31	−15	4	16	29	20	17	82	4.97	+3.4	10	12,336	ne.	56	nw.	18	8	14	9	5.7	48.2	T.
North Dakota.							**23.1**	**+2.5**										**82**	**0.44**	**−0.5**										**5.1**		
Moorhead	940	8	57	28.98	30.03	−0.05	25.7	+4.3	55	30	34	−27	4	17	39	23	20	85	0.40	−0.7	5	7,562	nw.	44	nw.	28	16	7	8	4.0	4.0	....
Bismarck	1,674	8	57	28.22	30.08	+ .02	24.3	+2.2	63	30	34	−24	4	15	40	21	18	80	0.60	−0.4	5	8,217	nw.	51	nw.	24	7	16	8	5.4	5.6	....
Devils Lake	1,482	11	44	28.36	30.00	− .05	21.8	+3.3	59	30	30	−21	4	13	31	19	17	85	0.30	−0.7	6	8,719	w.	44	nw.	28	8	13	10	5.7	2.7	....
Grand Forks	835	12	89	.....	.....	.....	21.6	.....	54	30	31	−33	4	12	40	21	....	....	0.34	.....	3	.....	nw.	47	nw.	28	24	6	1	....	3.6	T.
Williston	1,872	41	48	27.97	30.03	− .01	20.8	−0.8	46	29	30	−26	3	12	42	19	15	76	0.47	−0.2	10	6,568	w.	36	w.	28	10	15	6	5.2	3.9	T.
Upper Mississippi Valley.							**38.0**	**+2.0**										**70**	**2.66**	**+0.3**										**5.8**		
Minneapolis	918	10	208	28.97	29.98	.....	27.2	.....	57	30	34	−15	4	20	30	....	....	....	2.74	+1.1	8	10,236	w.	38	ne.	16	11	9	11	5.5	20.9	T.
St. Paul	837	201	236	29.05	29.98	−0.07	27.3	−0.9	56	30	35	−14	4	20	34	....	....	....	2.09	+0.5	8	10,766	nw.	44	n.	31	8	14	9	5.8	22.2	T.
La Crosse	714	11	48	29.19	29.95	− .09	31.0	+0.1	61	30	40	−11	5	22	35	....	....	....	2.01	+0.4	10	5,059	nw.	24	nw.	29	7	7	17	6.7	9.3	....
Madison	974	70	78	28.92	30.00	− .04	31.8	+1.7	65	31	40	− 4	5	24	32	28	23	73	2.00	−0.2	8	9,122	w.	33	e.	13	5	10	16	6.9	7.2	....
Wausau	1,247	4	....	28.58	29.96	.....	26.5	.....	50	22	35	−24	5	18	42	....	....	....	3.07	.....	12	.....	nw.	....	....	....	4	11	16	7.0	17.4	T.
Charles City	1,015	10	49	28.89	30.00	− .05	30.4	+2.0	67	30	39	− 6	4	22	37	27	23	79	2.47	+0.6	7	6,844	nw.	28	se.	16	7	14	10	5.9	16.1	....
Davenport	606	71	79	29.33	30.01	− .02	38.6	+3.2	70	30	48	6	4	29	36	33	28	70	1.76	−0.4	6	8,257	nw.	35	sw.	16	6	11	14	6.5	0.5	....
Des Moines	861	84	97	29.06	29.99	− .05	37.5	+1.8	80	30	48	1	4	27	42	32	27	68	2.30	+0.6	8	7,358	nw.	40	sw.	16	9	10	12	5.7	4.2	....
Dubuque	698	81	96	29.25	30.02	− .02	34.8	+1.6	65	30	44	3	5	26	35	30	25	71	1.56	−0.6	9	6,869	nw.	27	nw.	17	8	11	12	6.0	2.5	....
Keokuk	614	64	78	29.34	30.03	.00	41.2	+3.3	77	30	51	6	4	31	37	34	27	63	3.46	+1.1	8	8,976	w.	40	sw.	16	13	14	4	4.3	T.	....
Cairo	356	87	93	29.68	30.07	+ .03	49.4	+2.4	78	31	58	16	5	41	27	43	37	66	3.60	−0.4	12	10,342	s.	43	n.	4	12	8	11	5.3	2.8	....
Peoria	609	11	45	29.35	30.03	.00	40.0	+3.0	77	31	50	5	5	30	36	34	30	73	2.26	−0.7	7	8,504	s.	37	w.	17	9	14	8	5.5	T.	....
Springfield, Ill	644	10	91	29.33	30.02	− .01	42.6	+3.5	83	31	52	10	5	33	33	37	30	67	5.17	+2.1	10	9,445	s.	35	w.	17	9	9	13	5.7	0.3	....
Hannibal	534	74	109	29.44	30.03	+ .01	43.0	+1.4	80	30	54	8	4	32	40	....	....	....	3.95	+1.2	11	10,126	sw.	46	sw.	7	12	11	8	4.7	1.8	....
St. Louis	567	265	303	29.42	30.04	+ .01	46.6	+3.1	80	31	56	14	4	37	31	40	34	68	1.80	−1.6	12	14,241	s.	52	sw.	10	10	11	10	5.5	0.3	....
Missouri Valley.							**37.8**	**+1.7**										**68**	**1.90**	**±0.0**										**4.8**		
Columbia, Mo	781	11	84	29.18	30.03	0.00	44.4	+3.0	82	30	55	3	5	34	36	....	....	....	3.52	+0.5	10	9,382	s.	40	sw.	16	10	11	10	5.0	2.5	....
Kansas City	963	161	181	28.96	30.01	− .01	44.2	+3.4	81	30	55	8	4	34	39	37	28	57	2.89	+0.1	8	11,866	n.	47	nw.	7	18	5	8	4.1	3.2	....
St. Joseph	967	11	49	28,95	30.01	.....	42.6	.....	82	30	54	7	4	31	43	35	25	56	1.48	.....	6	9,627	nw.	48	nw.	7	14	11	6	4.5	0.1	....
Springfield, Mo	1,324	98	104	28.62	30.04	+ .02	47.0	+3.5	80	31	58	10	5	36	36	39	32	63	2.31	−1.8	12	11,571	s.	48	se.	15	18	5	8	3.8	4.4	....
Iola	984	11	50	28.95	30.03	+ .02	45.8	+3.2	81	22	58	8	5	34	42	....	....	....	3.55	+1.2	8	8,233	s.	34	s.	6	16	9	6	3.4	4.5	....
Topeka	987	85	101	.....	.....	.....	44.0	+3.1	83	30	56	9	4	32	42	....	....	....	1.04	−1.2	6	10,630	nw.	44	w.	16	15	9	7	3.7	0.4	....
Drexel	1,299	10	54	28.58	30.00	.....	36.0	.....	84	30	47	− 2	4	25	44	30	24	72	1.39	.....	8	9,971	nw.	40	se.	16	11	10	10	5.2	5.1	....
Lincoln	1,189	11	84	28.71	30.01	− .01	39.0	+3.0	88	30	50	0	4	28	43	31	23	60	1.27	−0.1	7	10,254	n.	54	nw.	16	15	11	5	4.0	2.7	....
Omaha	1,105	115	122	28.80	30.01	− .03	38.5	+2.5	84	30	49	3	4	28	40	32	24	62	1.35	0.0	7	7,372	nw.	38	n.	31	12	12	7	4.9	3.5	....
Valentine	2,598	47	54	27.26	30.06	+ .03	29.0	−2.9	79	30	39	− 3	4	19	33	25	22	82	1.16	0.0	7	7,874	nw.	36	nw.	16	13	10	8	5.1	9.4	....
Sioux City	1,135	94	164	28.76	30.01	+ .04	33.4	+0.8	78	30	41	− 1	4	25	38	29	26	77	1.82	+0.6	6	10,510	nw.	56	nw.	16	10	7	14	5.9	13.8	....
Huron	1,306	59	74	28.62	30.07	+ .01	27.0	+0.3	66	30	35	−16	4	19	35	24	21	81	1.02	0.0	4	9,487	nw.	37	n.	16	9	9	13	5.7	10.5	....
Pierre	1,572	70	75	28.35	30.07	+ .02	29.6	+0.1	74	30	38	−18	4	21	40	26	21	74	0.53	−0.8	5	7,901	nw.	46	nw.	30	11	7	13	5.9	6.4	T.
Yankton	1,233	49	57	28.67	30.02	− .03	31.4	+0.2	79	30	40	− 8	4	23	41	....	....	....	2.36	+1.2	7	7,293	w.	35	ne.	16	10	12	9	5.6	20.2	....

TABLE I.—*Climatological data for Weather Bureau Stations, March, 1917*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Total.	Departure from normal.	Days with .01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope.							**25.3**	**−5.6**										**69**	**0.92**	**−0.2**										**5.1**		
Billings	3,140	5	....	......	......	......	25.0	......	67	29	37	−16	13	13	46	....	....	....	0.66	......	......	......	sw.	....	......	....	11	14	6	....	9.8	....
Havre	2,505	11	44	27.30	30.03	−0.03	22.0	−5.3	65	29	32	−24	3	12	54	21	18	83	0.18	−0.3	8	6,945	sw.	36	sw.	24	11	17	3	4.6	1.8	....
Helena	4,110	87	114	25.74	30.08	+ .07	24.1	−6.9	62	29	33	− 7	3	15	34	20	14	67	0.55	−0.2	12	6,463	sw.	37	sw.	24	7	14	10	5.8	7.3	T.
Kalispell	2,962	11	34	26.90	30.05	+ .06	26.2	−6.8	49	27	36	− 5	2	16	35	23	19	75	1.09	0.0	14	3,777	se.	31	sw.	27	4	18	9	5.9	8.8	0.1
Miles City	2,371	48	55	27.47	30.11	+ .09	25.0	−3.6	51	24	36	−18	3	14	50	21	18	78	0.65	−0.1	6	4,571	ne.	39	w.	24	13	15	3	4.2	5.5	T.
Rapid City	3,259	50	58	26.56	30.10	+ .09	27.8	−3.8	71	29	39	− 7	4	17	44	23	16	62	0.96	−0.1	7	7,562	n.	60	n.	30	6	14	11	6.3	9.7	0.4
Cheyenne	6,088	84	101	23.88	30.03	+ .07	25.6	−7.4	64	29	36	0	3	16	43	21	11	54	0.69	−0.3	11	14,014	w.	64	w.	23	12	11	8	4.9	12.7	0.7
Lander	5,372	60	68	24.55	30.04	......	27.0	−4.3	65	29	39	− 3	17	15	38	22	14	59	0.72	−0.9	6	4,285	sw.	46	w.	24	12	15	4	4.3	11.6	....
Sheridan	3,790	10	47	26.06	30.10	......	24.0	......	62	29	36	−10	12	11	45	20	14	71	1.31	......	11	4,580	nw.	48	nw.	30	15	6	10	4.5	14.9	T.
Yellowstone Park	6,200	11	48	23.77	30.14	+ .12	16.8	−9.7	49	29	27	−15	1	7	34	14	10	75	1.99	−0.2	13	7,072	s.	39	sw.	23	9	12	10	5.6	21.9	24.5
North Platte	2,821	11	51	27.05	30.06	+ .06	33.0	−2.3	80	30	45	3	3	21	41	27	21	68	1.48	+0.6	8	6,925	w.	35	nw.	6	13	7	11	4.8	14.1	....
Middle Slope.							**41.8**	**−0.7**										**55**	**0.85**	**−0.6**										**3.6**		
Denver	5,292	106	113	24.63	30.01	+0.06	33.2	−5.5	72	30	44	4	16	22	38	27	18	58	0.95	0.0	10	6,359	nw.	38	w.	26	15	7	9	4.5	16.1	1.2
Pueblo	4,685	80	86	25.20	29.96	+ .04	37.6	−3.0	76	30	53	− 2	4	22	53	28	14	46	0.44	−0.4	7	7,267	nw.	48	nw.	6	18	8	5	2.9	5.8	....
Concordia	1,392	50	58	28.51	30.02	+ .01	41.6	+0.9	89	30	55	7	4	28	50	33	24	59	1.49	0.0	4	8,648	nw.	42	nw.	7	15	9	7	4.5	4.5	....
Dodge	2,509	11	51	27.38	30.03	+ .06	41.8	+0.1	88	30	58	5	4	26	52	33	25	58	0.36	−0.5	2	9,781	n.	41	n.	16	19	9	3	3.0	4.0	....
Wichita	1,358	139	158	28.53	29.98	− .01	45.7	+1.6	83	30	58	12	4	33	41	37	25	53	0.66	−1.6	5	13,663	s.	60	w.	6	19	8	4	3.1	1.0	....
Altus	1,410	5	....	......	......	......	52.8	......	91	30	69	15	4	37	50	....	....	....	0.18	......	2	......	se.	....	......	....	22	0	9	....	T.	....
Muskogee	652	4	....	......	......	......	48.9	......	76	25	60	19	5	37	39	....	....	....	0.64	......	6	......	s.	....	......	....	13	2	16	....	0.0	....
Oklahoma	1,214	10	47	28.72	30.02	+ .04	51.0	+1.8	84	30	64	18	4	38	37	40	30	54	1.20	−1.2	5	14,005	s.	46	s.	6	16	7	8	3.6	0.4	....
Southern Slope.							**53.4**	**+0.2**										**38**	**0.22**	**−0.7**										**2.9**		
Abilene	1,738	10	52	28.19	30.00	+0.04	56.8	+1.9	90	31	71	16	4	43	40	43	26	40	0.27	−1.1	3	10,306	s.	39	s.	30	19	6	6	3.4	0.5	....
Amarillo	3,676	10	49	26.22	29.97	+ .02	46.2	+1.2	86	30	63	6	4	29	48	34	20	47	0.25	−0.4	1	9,332	sw.	44	sw.	6	25	4	2	3.0	2.5	....
Del Rio	944	64	71	29.04	30.03	+ .08	62.2	+0.5	92	22	74	27	5	51	37	....	....	....	0.05	−1.1	2	8,182	e.	37	nw.	13	14	12	5	3.8	0.0	....
Roswell	3,566	75	85	26.32	29.95	+ .05	48.6	−2.7	84	30	66	19	4	32	52	35	10	28	0.29	−0.2	1	8,137	s.	46	sw.	10	27	2	2	1.5	2.3	....
Southern Plateau.							**46.4**	**−4.5**										**37**	**0.17**	**−0.4**										**1.5**		
El Paso	3,762	110	133	26.16	29.93	+0.05	53.3	−2.6	84	29	68	21	4	39	43	38	12	23	0.07	−0.3	1	9,862	w.	54	nw.	31	28	2	1	1.1	0.4	....
Santa Fe	7,013	57	66	23.15	29.94	+ .05	35.6	−3.8	68	29	47	7	4	24	35	27	14	45	0.27	−0.5	4	7,824	nw.	37	sw.	22	19	10	2	2.9	3.6	0.2
Flagstaff	6,908	8	57	23.29	30.00	+ .09	29.1	−6.8	65	29	44	− 9	13	14	45	24	....	....	0.50	......	4	......	sw.	44	sw.	9	23	7	1	....	5.3	T.
Phoenix	1,108	76	81	28.84	30.00	+ .09	56.2	−4.3	91	28	72	30	4	40	44	45	33	51	0.15	−0.3	1	4,250	w.	24	w.	22	27	3	1	1.7	0.2	....
Yuma	141	9	54	29.88	30.03	+ .09	61.4	−3.1	94	28	76	35	13	46	41	45	22	28	T.	−0.4	0	5,579	n.	39	n.	3	31	0	0	0.3	0.0	....
Independence	3,910	11	42	25.99	30.03	+ .09	43.1	−6.5	76	29	59	20	2	27	43	33	19	44	0.01	−0.5	1	......	n.	....	......	....	18	13	0	....	0.0	....
Needles	488	4	....	29.49	30.00	......	58.0	......	95	28	76	29	16	40	52	....	....	....	0.00	......	0	......	sw.	....	......	....	24	3	4	....	0.0	....
Middle Plateau.							**33.7**	**−7.2**										**54**	**0.83**	**−0.4**										**4.3**		
Reno	4,532	74	81	25.52	30.15	+0.17	35.5	−5.5	66	27	48	13	15	23	37	29	19	56	0.74	−0.5	7	5,537	w.	48	sw.	29	15	10	6	4.1	9.9	....
Tonopah	6,090	12	20	24.06	30.10	......	33.0	......	66	28	43	10	2	23	29	26	14	47	0.03	−1.3	1	7,587	nw.	38	nw.	5	15	13	3	3.6	0.2	....
Winnemucca	4,344	18	56	25.67	30.15	+ .14	32.8	−6.8	66	28	44	5	15	21	34	28	20	63	0.58	−0.4	10	6,074	sw.	43	sw.	29	9	9	13	5.7	4.7	....
Modena	5,479	10	43	24.60	30.05	+ .09	31.0	−8.2	68	29	45	− 1	23	17	40	25	14	55	0.68	−0.6	7	8,826	w.	58	sw.	9	19	9	3	2.8	6.0	....
Salt Lake City	4,360	147	189	25.65	30.11	+ .13	33.0	−8.4	70	29	41	14	3	25	29	27	18	57	2.61	+0.6	9	5,760	nw.	60	w.	9	7	15	9	5.5	33.0	....
Grand Junction	4,602	82	96	25.37	30.00	+ .06	36.2	−7.3	72	29	47	14	6	25	40	28	16	48	0.32	−0.4	7	6,508	nw.	42	w.	25	16	8	7	4.0	4.8	....
Northern Plateau.							**32.7**	**−7.5**										**68**	**0.97**	**−0.6**										**7.0**		
Baker	3,471	48	53	26.49	30.17	+0.14	25.3	−10.2	52	28	35	−12	1	16	29	23	19	76	0.72	−0.7	12	5,321	se.	24	w.	29	8	11	12	5.8	4.7	....
Boise	2,739	78	86	27.26	30.19	+ .16	33.2	−9.0	60	29	41	15	2	26	30	29	22	64	1.75	+0.3	14	4,492	se.	35	sw.	24	5	9	17	7.1	18.9	....
Lewiston	757	40	48	29.31	30.14	+ .11	38.8	−5.2	57	27	46	14	1	32	23	....	....	....	0.45	−0.8	12	4,423	e.	33	s.	27	2	9	20	7.7	0.6	....
Pocatello	4,477	60	68	25.49	30.15	+ .14	26.6	−10.3	56	29	34	1	18	19	37	24	19	74	1.29	−0.5	12	8,780	se.	50	sw.	30	2	16	13	6.7	15.1	T.
Spokane	1,929	101	110	27.99	30.10	+ .09	32.7	−6.2	51	27	41	8	1	25	28	29	23	68	1.07	−0.4	11	6,182	sw.	40	sw.	23	2	9	20	7.5	9.7	T.
Walla Walla	991	57	65	29.04	30.14	+ .12	39.8	−4.2	63	28	47	14	1	33	26	34	25	58	0.52	−1.4	9	5,844	sw.	32	sw.	23	4	7	20	7.3	T.	....
North Pacific Coast Region.							**41.1**	**−3.5**										**81**	**4.64**	**±0.0**										**5.2**		
North Head	211	11	56	29.90	30.14	+0.13	40.8	−4.1	52	16	45	32	1	37	15	40	39	92	6.17	+0.9	24	14,191	e.	74	se.	28	5	6	20	7.2	T.	....
North Yakima	1,071	4	....	......	......	......	38.4	......	61	27	50	13	2	27	34	....	....	....	0.31	......	4	......	nw.	....	......	....	10	12	9	....	T.	....
Port Angeles	42	8	48	30.07	30.10	......	39.2	......	51	17	46	25	2	32	21	....	....	....	2.19	0.0	15	5,416	w.	34	sw.	24	11	9	11	5.3	T.	....
Seattle	125	215	250	29.99	30.12	+ .13	41.0	−3.2	56	17	47	28	2	35	23	37	33	76	2.96	−0.6	16	9,072	s.	48	s.	20	5	7	19	7.4	1.0	....
Tacoma	213	113	120	29.89	30.12	+ .12	40.9	−3.3	58	17	47	27	2	34	26	38	35	82	4.23	+0.2	17	5,596	sw.	34	sw.	23	2	14	15	6.8	2.0	....
Tatoosh Island	109	7	57	29.96	30.06	+ .10	40.4	−2.5	48	9	44	33	7	37	12	39	36	86	7.83	−0.7	24	13,069	w.	70	sw.	23	6	16	9	5.9	0.8	....
Medford	1,425	4	....	......	......	......	39.9	......	63	28	50	14	1	30	32	....	....	....	1.88	......	14	......	nw.	....	......	....	4	10	17	....	1.0	....
Portland, Oreg.	153	68	106	30.00	30.16	+ .14	42.6	−3.7	59	17	49	29	2	36	25	39	34	73	5.33	+0.2	21	5,419	sw.	28	sw.	22	5	6	20	7.5	0.2	....
Roseburg	510	9	57	29.67	30.23	+ .19	42.6	−4.0	65	28	51	26	16	34	25	39	34	77	3.74	−0.2	20	2,669	s.	22	w.	28	3	16	12	6.5	1.0	....
Middle Pacific Coast Region.							**47.9**	**−3.5**										**66**	**1.77**	**−2.4**										**3.3**		
Eureka	62	73	89	30.21	30.28	+0.22	43.8	−4.2	59	28	50	29	1	37	25	41	38	82	5.01	−2.0	20	5,682	se.	31	n.	5	8	10	13	6.1	0.0	....
Mount Tamalpais	2,375	11	18	27.68	30.20	+ .14	42.6	−3.5	66	27	50	28	14	37	20	37	30	65	1.46	−3.7	5	15,900	nw.	69	nw.	25	16	11	4	3.6	0.9	....
Point Reyes Light	490	7	18	29.64	30.16	......	45.8	−3.8	55	3	50	36	22	42	11	....	....	....	0.30	......	5	20,638	nw.	73	nw.	21	20	5	6	3.5	0.0	....
Red Bluff	332	50	56	29.81	30.18	+ .14	49.6	−4.2	76	28	60	32	14	39	27	41	30	51	1.25	−2.5	6	4,904	nw.	27	nw.	21	17	9	5	3.5	0.0	....
Sacramento	69	106	117	30.11	30.18	+ .15	50.8	−3.4	77	27	61	34	12	40	30	45	37	65	0.70	−2.3	4	6,370	nw.	32	nw.	25	23	6	2	2.3	0.0	....
San Francisco	155	209	213	30.03	30.20	+ .14	51.7	−1.0	72	26	59	41	11	44	25	45	39	68	1.42	−1.7	4	5,686	nw.	33	sw.	8	24	6	1	1.8	0.0	....
San Jose	141	12	110	30.04	30.20	......	49.0	−4.7	75	26	61	31	2	37	37	....	....	....	0.77	−2.2	4	5,040	nw.	27	w.	21	26	3	2	2.0	0.0	....
South Pacific Coast Region.							**54.0**	**−1.7**										**62**	**0.36**	**−2.2**										**2.2**		
Fresno	327	89	98	29.81	30.17	+0.16	51.3	−3.6	81	28	63	32	2	39	33	44	36	60	0.56	−1.2	4	5,805	nw.	34	nw.	29	22	8	1	2.5	0.0	....
Los Angeles	338	159	191	29.73	30.10	+ .08	56.7	−1.1	79	27	67	39	12	47	30	46	36	54	0.18	−2.8	2	4,543	sw.	31	nw.	22	23	6	2	2.0	0.0	....
San Diego	87	62	70	30.00	30.10	+ .08	54.6	−1.6	75	28	63	39	3	46	24	48	42	67	0.26	−1.4	5	4,645	nw.	24	nw.	2	21	7	3	2.5	0.0	....
San Luis Obispo	201	32	40	29.97	30.19	+ .13	53.2	−0.6	81	27	64	30	11	42	34	45	39	65	0.44	−3.5	5	4,146	n.	22	ne.	6	25	5	1	1.6	0.0	....
West Indies.																																
San Juan, P. R.	82	8	54	29.99	30.08	+0.06	74.1	......	80	20	78	65	29	70	13	....	....	....	1.25	−1.9	17	13,064	ne.	44	e.	1	17	11	3	3.8	0.0	....
Panama Canal.																																
Balboa Heights	118	7	97	29.75	29.87	......	80.0	......	90	3	88	67	25	72	23	72	70	79	0.02	−0.6	2	9,292	n.	33	n.	19	6	25	0	4.5	0.0	....
Colon	25	5	71	29.86	29.89	......	78.8	......	84	4	82	73	5	76	11	74	71	79	0.76	−0.9	10	12,923	n.	32	ne.	19	8	9	14	5.5	0.0	....
Alaska.																																
Juneau	80	11	49	......	......	......	33.4	......	45	6	38	18	30	28	21	30	24	72	4.20	......	19	4,079	s.	36	ne.	12	6	3	22	7.5	27.9	2.5

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during March, 1917, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	1			0.12														0.08			
Albany, N. Y	27			0.54														0.26			
Alpena, Mich.	10-11			0.44														*			
Amarillo, Tex	3			0.25														*			
Anniston, Ala	16-17	D. N. p. m.	7:10 a. m.	0.91	1:43 a. m.	2:01 a. m.	0.12	0.16	0.28	0.40	0.50										
	26	1:19 p. m.	5:00 p. m.	2.58	1:59 p. m.	3:35 p. m.	0.10	0.10	0.21	0.39	0.61	0.93	1.07	1.08	1.10	1.19	1.48	1.67	1.86	2.33	
Asheville, N. C	24			0.76														0.36			
Atlanta, Ga	23-24	7:35 p. m.	6:35 a. m.	1.47	3:03 a. m.	3:15 a. m.	0.54	0.13	0.43	0.49											
Atlantic City, N. J	8			0.95														0.44			
Augusta, Ga	4	1:40 p. m.	5:10 p. m.	1.12	1:48 p. m.	1:57 p. m.	0.01	0.38	0.63												
Baker, Oreg	9			0.17														*			
Baltimore, Md	27			0.49														0.17			
Bentonville, Ark	15			0.66														0.52			
Binghamton, N. Y	27			0.43														0.19			
Birmingham, Ala	2	5:15 p. m.	6:47 p. m.	0.74	5:44 p. m.	6:30 p. m.	0.01	0.16	0.25	0.32	0.34	0.42	0.45	0.47	0.54	0.68	0.71				
	2	6:51 p. m.	8:35 p. m.	0.96	7:04 p. m.	7:30 p. m.	0.02	0.23	0.38	0.65	0.71	0.79	0.83								
	16-17	9:12 p. m.	D. N. a. m.	0.95	12:10 a. m.	12:32 a. m.	0.13	0.40	0.58	0.65	0.69	0.73									
	23-24	4:54 p. m.	D. N. a. m.	1.64	10:48 p. m.	11:16 p. m.	0.56	0.11	0.23	0.33	0.43	0.50	0.58								
	26	12:01 p. m.	2:26 p. m.	1.44	12:34 p. m.	1:21 p. m.	0.06	0.17	0.37	0.52	0.74	0.94	1.09	1.14	1.17	1.24	1.26				
Bismarck, N. Dak	10-11			0.42														*			
Block Island, R. I	27			0.81														0.21			
Boise, Idaho	9-10			0.78														*			
Boston, Mass	27			0.81														0.19			
Buffalo, N. Y	4-5			0.82														*			
Burlington, Vt	5			0.87														*			
Cairo, Ill	23	12:07 p. m.	2:50 p. m.	0.76	12:58 p. m.	1:14 p. m.	0.03	0.10	0.35	0.64	0.69										
Canton, N. Y	11			0.42														*			
Charles City, Iowa	13			0.89														*			
Charleston, S. C	26-27	10:22 p. m.	D. N. a. m.	1.05	12:28 a. m	12:50 a. m.	0.30	0.08	0.21	0.42	0.65	0.72									
Charlotte, N. C	24	D. N. a. m.	8:45 a. m.	1.62	5:49 a. m.	6:13 a. m.	0.56	0.08	0.24	0.35	0.44	0.51									
Chattanooga, Tenn	23-24	5:07 p. m.	2:30 a. m.	1.37	10:27 p. m.	10:52 p. m.	0.37	0.13	0.28	0.30	0.58	0.66									
	26-27	11:25 p. m.	4:08 a. m.	1.05	11:57 p. m.	12:21 a. m.	0.03	0.20	0.35	0.51	0.61	0.66									
Cheyenne, Wyo	11-12			0.29														*			
Chicago, Ill	13			1.15														0.31			
Cincinnati, Ohio	23	3:12 p. m.	7:10 p. m.	0.78	3:47 p. m.	3:57 p. m.	0.11	0.20	0.38												
Cleveland, Ohio	4-5			0.55														*			
Columbia, Mo	23	12:35 a. m.	D. N. a. m.	0.80	1:35 a. m.	1:51 a. m.	0.02	0.31	0.47	0.54	0.57										
Columbia, S. C	1			0.55														0.40			
Columbus, Ohio	23			0.92														0.36			
Concord, N. H	27-28			0.78														*			
Concordia, Kans	12-13			0.73														*			
Corpus Christi, Tex	9			0.07														0.05			
Dallas, Tex	16	3:27 a. m.	6:34 a. m.	1.29	3:33 a. m.	4:09 a. m.	0.02	0.08	0.18	0.25	0.45	0.55	0.63	0.80	0.84						
Davenport, Iowa	12-13			1.09														*			
Dayton, Ohio	11	3:58 p. m.	5:50 p. m.	0.79	5:12 p. m.	5:29 p. m.	0.05	0.07	0.33	0.62	0.73										
Del Rio, Tex	3			0.04														0.02			
Denver, Colo	11-12			0.26														*			
Des Moines, Iowa	12-13			1.40														*			
Detroit, Mich	13-14			0.60														*			
Devils Lake, N. Dak	12-13			0.18														*			
Dodge City, Kans	13			0.20														*			
Drexel, Nebr	15-16			0.53														*			
Dubuque, Iowa	12-13			0.97														*			
Duluth, Minn	13-14			2.04														*			
Eastport, Me	5-6			0.90														*			
Elkins, W. Va	11-12			1.74														*			
El Paso, Tex	3			0.07														*			
Erie, Pa	14			0.83														*			
Escanaba, Mich	16-17			0.79														*			
Eureka, Cal	8			0.97														0.36			
Evansville, Ind	11			0.27														0.26			
Flagstaff, Ariz	11			0.24														*			
Fort Smith, Ark	2			0.32														0.14			
Fort Wayne, Ind	10-11			1.12														*			
Fort Worth, Tex	1			1.27														0.41			
Fresno, Cal	9			0.41														0.15			
Galveston, Tex	9			0.51														0.33			
Grand Haven, Mich	11			0.18														0.18			
Grand Junction, Colo	22			0.16														*			
Grand Rapids, Mich	31			0.42														0.26			
Green Bay, Wis	23			0.96														*			
Hannibal, Mo	12-13	1:28 p. m.	5:15 a. m.	2.50	12:34 a. m.	1:07 a. m.	1.13	0.11	0.22	0.34	0.56	0.68	0.89	0.98							
Harrisburg, Pa	4			0.85														*			
Hartford, Conn	27			1.21														0.30			
Hatteras, N. C	5			0.73														0.32			
Havre, Mont	2			0.04														*			
Helena, Mont	9-10			0.15														*			
Houghton, Mich	16-17			1.54														*			
Houston, Tex	9			0.46														0.31			
Huron, S. Dak	15-16			0.68														*			
Independence, Cal	9			0.01														*			
Indianapolis, Ind	12-13			1.63														*			
Iola, Kans	12	2:40 p. m.	9:10 p. m.	1.42	5:41 p. m.	6:11 p. m.	0.32	0.08	0.10	0.19	0.27	0.73	0.95								
Jacksonville, Fla	27	10:35 a. m.	11:50 a. m.	0.59	10:47 a. m.	11:02 a. m.	0.01	0.16	0.28	0.37											
Juneau, Alaska	17-18			0.74														*			
Kalispell, Mont	25			0.55														*			
Kansas City, Mo	22	7:04 p. m.	8:00 p. m.	0.50	7:21 p. m.	7:33 p. m.	0.10	0.20	0.35	0.40											
Keokuk, Iowa	22-23	10:00 p. m.	7:20 a. m.	1.01	1:17 a. m.	1:30 a. m.	0.14	0.27	0.46	0.51											
Key West, Fla	7	D. N. a. m.	3:10 p. m.	2.34	9:31 a. m.	9:49 a. m.	0.28	0.19	0.35	0.54	0.61										
Knoxville, Tenn	23			1.30														0.61			
La Crosse, Wis	13-14			0.83														*			
Lander, Wyo	15			0.60														*			
Lansing, Mich	26			0.59														0.36			
Lewiston, Idaho	20			0.11														0.02			
Lexington, Ky	11			0.51														0.39			
Lincoln, Nebr	12-13			0.76														*			
Little Rock, Ark	23	9:25 a. m.	11:35 a. m.	0.80	10:37 a. m.	10:57 a. m.	0.17	0.15	0.20	0.42	0.57										
Los Angeles, Cal	9			0.12														0.05			
	11-12	8:33 p. m.	6:35 a. m.	1.42	8:48 p. m.	9:44 p. m.	0.01	0.16	0.46	0.62	0.69	0.82	0.96	1.03	1.05	1.06	1.09	1.24			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during March, 1917, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Louisville, Ky	23	2:33 p. m.	4:08 p. m.	0.88	3:01 p. m.	3:41 p. m.	0.03	0.05	0.14	0.33	0.38	0.44	0.51	0.58	0.78						
Ludington, Mich	10			0.46														0.20			
Lynchburg, Va	1			0.79														0.20			
Macon, Ga	3			0.75														0.46			
Madison, Wis	12-13			1.32														*			
Marquette, Mich	16-17			0.82														*			
Memphis, Tenn	15			0.47														0.42			
Meridian, Miss	3	9:05 a. m.	1:40 p. m.	0.60	9:45 a. m.	9:55 a. m.	0.02	0.20	0.32												
Miami, Fla	7	4:59 p. m.	7:55 p. m.	1.53	5:40 p. m.	6:33 p. m.	0.25	0.07	0.15	0.37	0.50	0.59	0.69	0.80	0.89	0.95	1.04	1.15			
Milwaukee, Wis	12-13			0.90														*			
Minneapolis, Minn	6-7			1.11														*			
Mobile, Ala	4			0.82														0.52			
Modena, Utah	21-22			0.36														*			
Montgomery, Ala	2-3	10:40 p. m.	9:37 a. m.	4.06	10:52 p. m.	11:05 p. m.	0.01	0.25	0.54	0.63											
					6:44 a. m.	7:42 a. m.	2.19	0.17	0.27	0.34	0.40	0.46	0.65	0.81	0.92	1.04	1.24	1.55			
	3-4	3:40 p. m.	11:45 a. m.	3.27	7:31 p. m.	8:04 p. m.	0.72	0.08	0.15	0.25	0.36	0.50	0.81	0.86							
Moorhead, Minn	13			0.20														*			
Mount Tamalpais, Cal	9			0.29														0.15			
Nantucket, Mass	5			1.65														0.24			
	22	5:50 p. m.	6:40 p. m.	0.47	6:04 p. m.	6:23 p. m.	0.01	0.11	0.14	0.31	0.45										
Nashville, Tenn	26-27	10:20 p. m.	D.N. a.m.	0.62	10:51 p. m.	11:04 p. m.	0.05	0.20	0.44	0.52											
Needles, Cal	‡																				
New Haven, Conn	27			1.43														0.32			
New Orleans, La	3-4	8:30 p. m.	7:55 a. m.	2.10	9:07 p. m.	9:42 p. m.	0.03	0.15	0.30	0.48	0.61	0.72	0.94	1.07							
New York, N. Y	8			0.45														0.20			
Norfolk, Va	27			0.96														0.57			
Northfield, Vt	27-28			0.71														*			
North Head, Wash	3-4			0.83														*			
North Platte, Nebr	15-16			0.63														*			
Oklahoma, Okla	22			0.40														0.39			
Omaha, Nebr	12-13			0.53														*			
Oswego, N. Y	27			0.46														*			
Palestine, Tex	16			0.50														0.26			
Parkersburg, W. Va	23			1.19														0.33			
Pensacola, Fla	2-3	11:10 p. m.	5:35 a. m.	1.22	11:46 p. m.	12:35 a. m.	0.11	0.09	0.21	0.39	0.57	0.58	0.58	0.62	0.73	0.79	0.86				
	3	8:15 p. m.	9:30 p. m.	0.79	8:47 p. m.	9:08 p. m.	0.02	0.07	0.30	0.50	0.73	0.77									
Peoria, Ill	13			1.22														0.50			
Philadelphia, Pa	4			1.43														*			
Phoenix, Ariz	12			0.15														0.06			
Pierre, S. Dak	15-16			0.37														*			
Pittsburgh, Pa	11			0.53														0.30			
Pocatello, Idaho	13-14			0.50														*			
Point Reyes Light, Cal	8			0.10														0.06			
Port Angeles, Wash	23			0.78														0.18			
Port Huron, Mich	31			0.17														0.14			
Portland, Me	27			0.83														0.43			
Portland, Oreg	5			0.38														0.25			
Providence, R. I	27			1.04														*			
Pueblo, Colo	22			0.21														*			
Raleigh, N. C	4			1.67														0.49			
Rapid City, S. Dak	15			0.55														*			
Reading, Pa	27			0.86														0.19			
Red Bluff, Cal	29	9:53 a. m.	1:10 p. m.	0.50	12:49 p. m.	1:04 p. m.	0.08	0.07	0.18	0.41											
Reno, Nev	9			0.39														*			
Richmond, Va	4			1.57														0.33			
Rochester, N. Y	4-5			1.21														*			
Roseburg, Oreg	26			0.45														0.13			
Roswell, N. Mex	3			0.29														*			
Sacramento, Cal	9			0.40														0.25			
Saginaw, Mich	26-27			0.72														*			
St. Joseph, Mo	13			0.89														0.41			
St. Louis, Mo	13			0.97														0.38			
St. Paul, Minn	16			0.78														*			
Salt Lake City, Utah	14-15			0.87														*			
San Antonio, Tex	23			0.02														0.02			
San Diego, Cal	11			0.14														0.05			
Sand Key, Fla	7			1.58														0.51			
Sandusky, Ohio	31			0.56														0.21			
Sandy Hook, N. J	27			0.42														0.28			
San Francisco, Cal	8-9			0.68														0.24			
San Jose, Cal	9			0.43														*			
San Luis Obispo, Cal	9			0.21														0.11			
Santa Fe, N. Mex	31			0.15														*			
Sault Ste. Marie, Mich	23			0.66														*			
Savannah, Ga	1	6:25 p. m.	8:48 p. m.	1.04	7:38 p. m.	7:52 p. m.	0.12	0.29	0.67	0.81											
Scranton, Pa	4-5			1.14														*			
Seattle, Wash	5			0.36														0.29			
Sheridan, Wyo	24			0.50														*			
Shreveport, La	2			0.62														0.34			
Sioux City, Iowa	15-16			1.18														*			
Spokane, Wash	4-5			0.31														*			
Springfield, Ill	12-13			3.13														*			
Springfield, Mo	12-13	11:41 p. m.	D. N. a. m.	0.89	1:19 a. m.	1.39 a. m.	0.11	0.12	0.28	0.40	0.50										
Syracuse, N. Y	4-5			0.78														*			
Tacoma, Wash	23			0.82														0.20			
Tampa, Fla	4			0.38														0.32			
Tatoosh Island, Wash	12			1.22														0.21			
Taylor, Tex	16			0.05														0.03			
Terre Haute, Ind	12-13	6:58 p. m.	11:20 a. m.	1.99	3:23 a. m.	4:01 a. m.	0.57	0.08	0.22	0.37	0.47	0.54	0.58	0.65	0.70						
Thomasville, Ga	4			0.96														0.64			
Toledo, Ohio	31			1.08														0.55			
Tonopah, Nev	11			0.03														*			
Topeka, Kans	13			0.63														0.34			
Trenton, N. J	4			0.81														*			
Valentine, Nebr	6			0.56														*			
Vicksburg, Miss	26	7:30 p. m.	8:35 p. m.	1.37	8:02 p. m.	8:28 p. m.	0.03	0.10	0.34	0.56	1.01	1.32	1.34								
Walla Walla, Wash	7			0.08														0.08			
Washington, D. C	4			1.24														*			
Wausau, Wis	7			1.22														*			

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TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during March, 1917, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Wichita, Kans	13			0.30														*			
Williston, N. Dak	11-12			0.26														*			
Wilmington, N. C	4-5	8:16 p. m.	D. N. a. m.	0.88	12:13 a. m.	12:33 a. m.	0.39	0.15	0.26	0.39	0.47										
Winnemucca, Nev	29-30			0.23														*			
Wytheville, Va	16			0.54														0.22			
Yankton, S. Dak	15-16			1.59														*			
Yellowstone Park, Wyo	24			0.46														*			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, March, 1917.*

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure.			Temperature.						Precipitation.		
		Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
		Feet.	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F	125												
Sydney, C. B. I	48	29.92	29.96	+0.08	27.5	+1.3	36.8	18.3	55	3	3.02	−1.91	13.0
Halifax, N. S	88	29.86	29.97	+ .03	30.7	+1.7	39.2	22.1	50	5	3.34	−2.12	7.3
Yarmouth, N. S	65	29.90	29.97	+ .02	31.6	+0.8	37.4	25.9	48	13	4.86	+0.01	17.7
Charlottetown, P. E. I	38	29.91	29.95	+ .05	27.0	+1.6	33.2	20.8	49	5	2.03	−1.18	7.9
Chatham, N. B	28	29.94	29.96	+ .06	25.5	+2.5	36.8	14.1	58	− 9	2.90	−0.57	19.8
Father Point, Que	20	29.94	29.97	+ .07	23.6	+3.3	31.0	16.2	50	−10	0.92	−1.81	3.2
Quebec, Que	296	29.65	29.99	+ .03	24.3	+3.1	32.6	16.1	51	− 5	4.05	+0.79	29.5
Montreal, Que	187	29.78	30.00	.00	26.9	+3.1	33.1	19.7	50	0	2.94	−0.85	19.0
Stonecliffe, Ont	489	29.35	29.98	− .03	25.5	+6.5	35.7	15.3	52	−16	1.84	−0.22	13.0
Ottawa, Ont	236	29.72	30.00	− .01	25.0	+3.5	34.1	15.8	53	− 6	3.00	+0.28	23.6
Kingston, Ont	285	29.70	30.02	+ .01	28.6	+3.0	35.8	21.4	53	− 4	2.51	−0.10	15.8
Toronto, Ont	379	29.58	30.01	+ .01	32.1	+4.8	39.0	25.3	63	7	2.32	−0.32	10.2
White River, Ont	1,244	28.57	29.94	− .09	11.9	−0.3	29.4	− 5.5	44	−48	2.02	+0.64	19.8
Port Stanley, Ont	592												
Southampton, Ont	656	29.24			28.5	+3.8	36.9	20.1	64	− 1	2.75	+0.10	10.2
Parry Sound, Ont	688	29.24	29.95	− .07	25.9	+4.8	34.4	17.5	55	− 4	4.40	+2.17	23.1
Port Arthur, Ont	644	29.24	29.97	− .08	22.0	+5.2	32.0	12.0	46	−16	0.99	+0.02	9.0
Winnipeg, Man	760	29.14	30.00	− .09	19.8	+7.5	28.6	11.1	45	−23	0.33	−0.70	3.3
Minnedosa, Man	1,690	28.10	29.99	− .07	18.1	+5.6	27.9	8.1	39	−28	0.20	−0.45	2.0
Qu'Appelle, Sask	2,115	27.62	29.95	− .09	17.9	+3.0	27.9	8.0	41	−26	0.60	−0.17	5.8
Medicine Hat, Alberta	2,144	27.58	29.92	− .08	25.3	−2.2	35.5	15.2	57	−22	0.14	−0.62	1.4
Swift Current, Sask	2,392	27.29	29.97	− .05	18.1	−3.9	27.3	8.8	42	−33	1.39	+0.58	13.5
Calgary, Alberta	3,428	26.28	29.93	− .02	25.5	−0.7	37.4	13.7	50	−10	0.16	−0.56	1.6
Banff, Alberta	4,521	25.22	29.95	+ .01	20.1	−0.1	32.3	7.9	42	−11	1.13	−0.28	11.3
Edmonton, Alberta	2,150	27.53	29.87	− .09	21.7	−2.5	32.5	11.0	43	− 8	0.12	−0.60	1.2
Prince Albert, Sask	1,450	28.32	29.94	− .14	18.1	+6.1	30.0	6.3	46	−34	0.90	+0.13	9.0
Battleford, Sask	1,592	28.16	29.97	− .09	16.7	+3.6	28.4	5.0	41	−31	0.30	−0.16	3.0
Kamloops, B. C	1,262	28.72	30.04	+ .12	33.3	−2.8	41.8	24.8	53	2	0.10	−0.47	1.0
Victoria, B. C	230	29.82	30.08	+ .11	40.3	−1.6	45.7	35.0	50	30	2.63	−0.49	0.3
Barkerville, B. C	4,180	25.52	29.91	+ .03	21.1	−5.0	28.3	13.8	37	2	3.25	+1.36	32.5
Hamilton, Bermuda	151	30.02	30.19	+ .11	61.3	−0.9	66.6	56.1	71	50	1.92	−3.21	0.0

* *See* Explanation of Tables in this REVIEW for January, p. 40.

Chart I. Hydrographs of Several Principal Rivers, March, 1917.

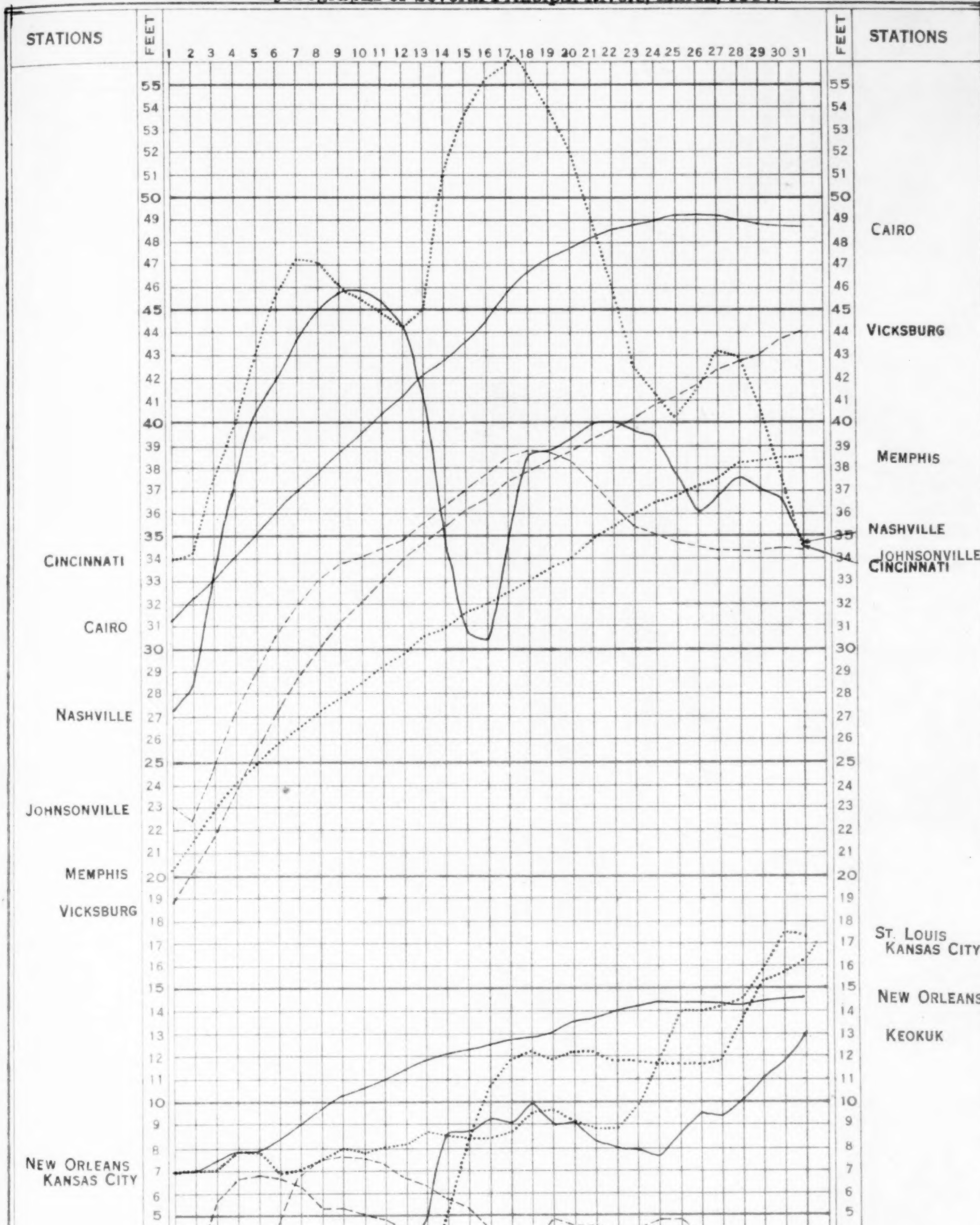


Chart II. Tracks of Centers of High Areas, March, 1917.

(Plotted by Charles A. Donnel.)

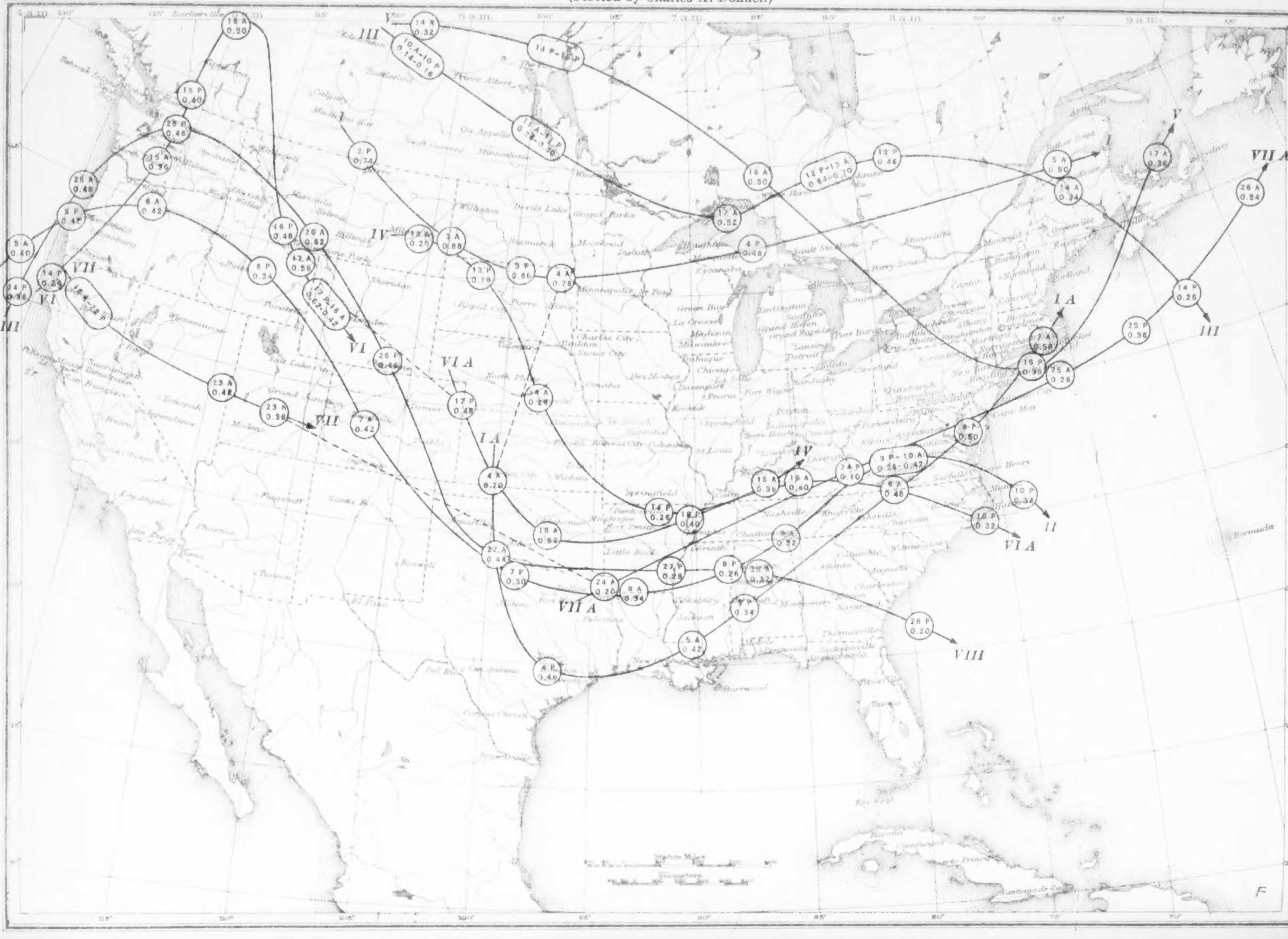


Chart III. Tracks of Centers of Low Areas, March, 1917.

Chart III. Tracks of Centers of Low Areas, March, 1917.

(Plotted by Charles A. Donnel.)

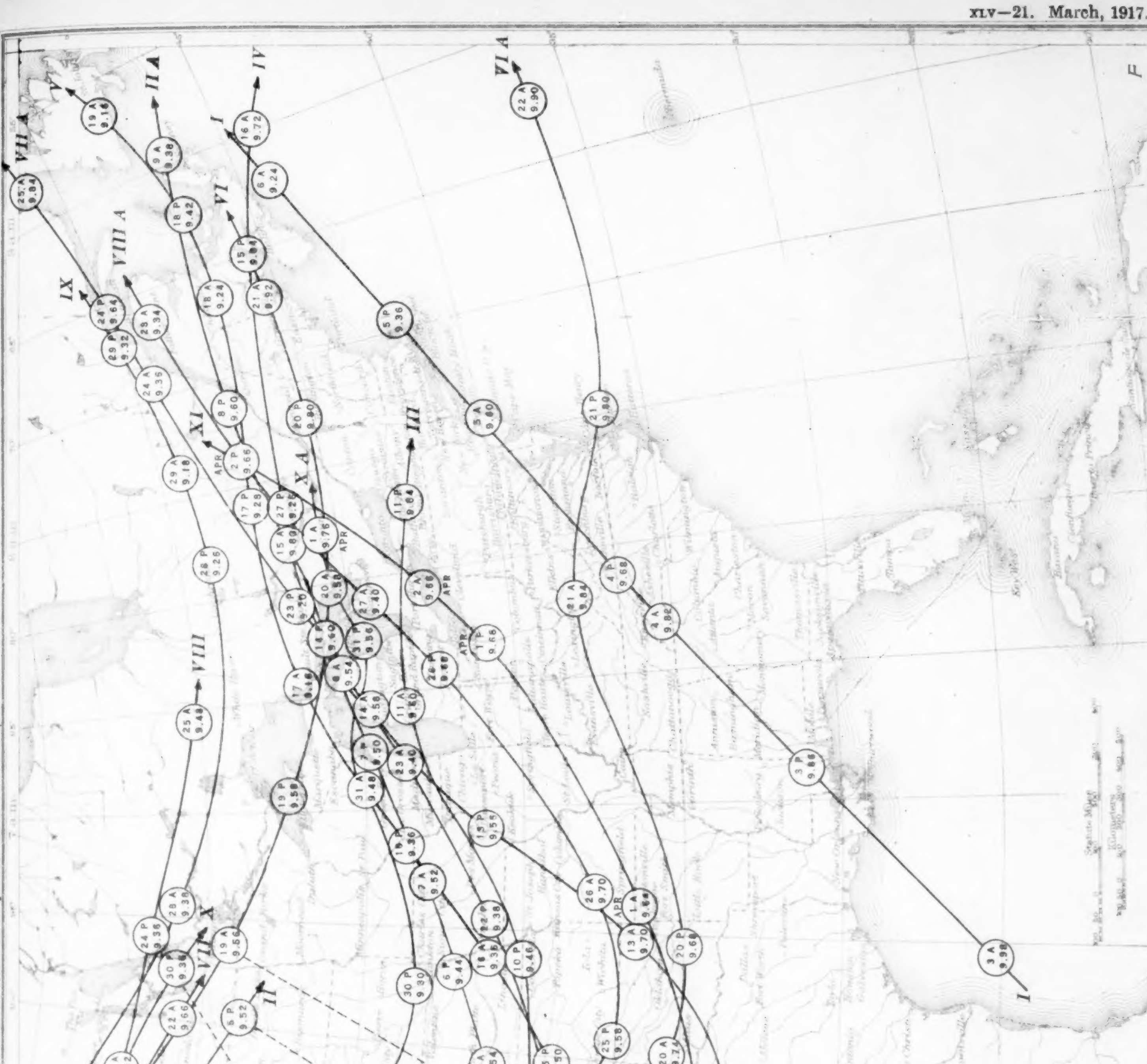
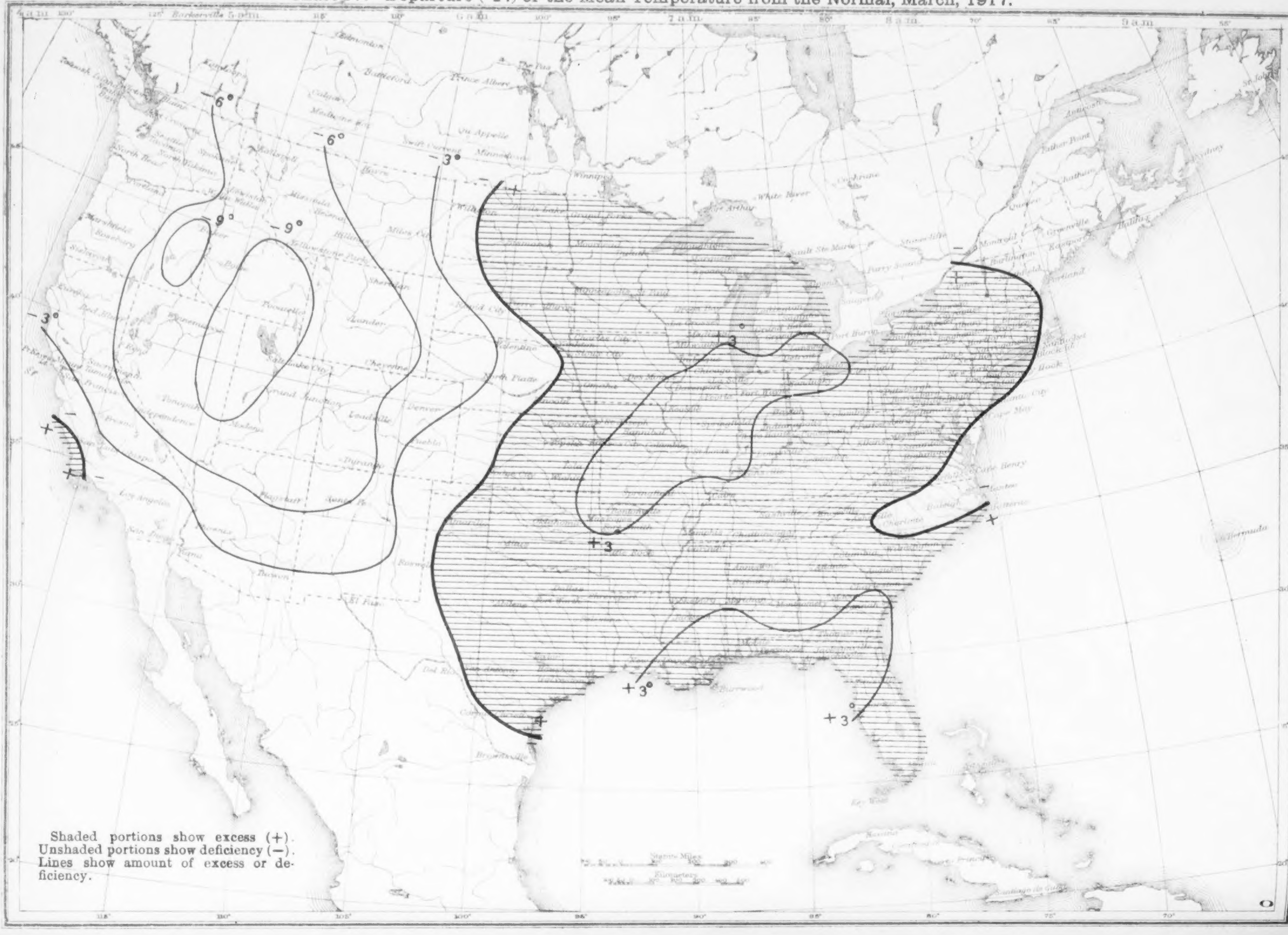


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, March, 1917.



Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart V. Total Precipitation, March, 1917.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, March, 1917.

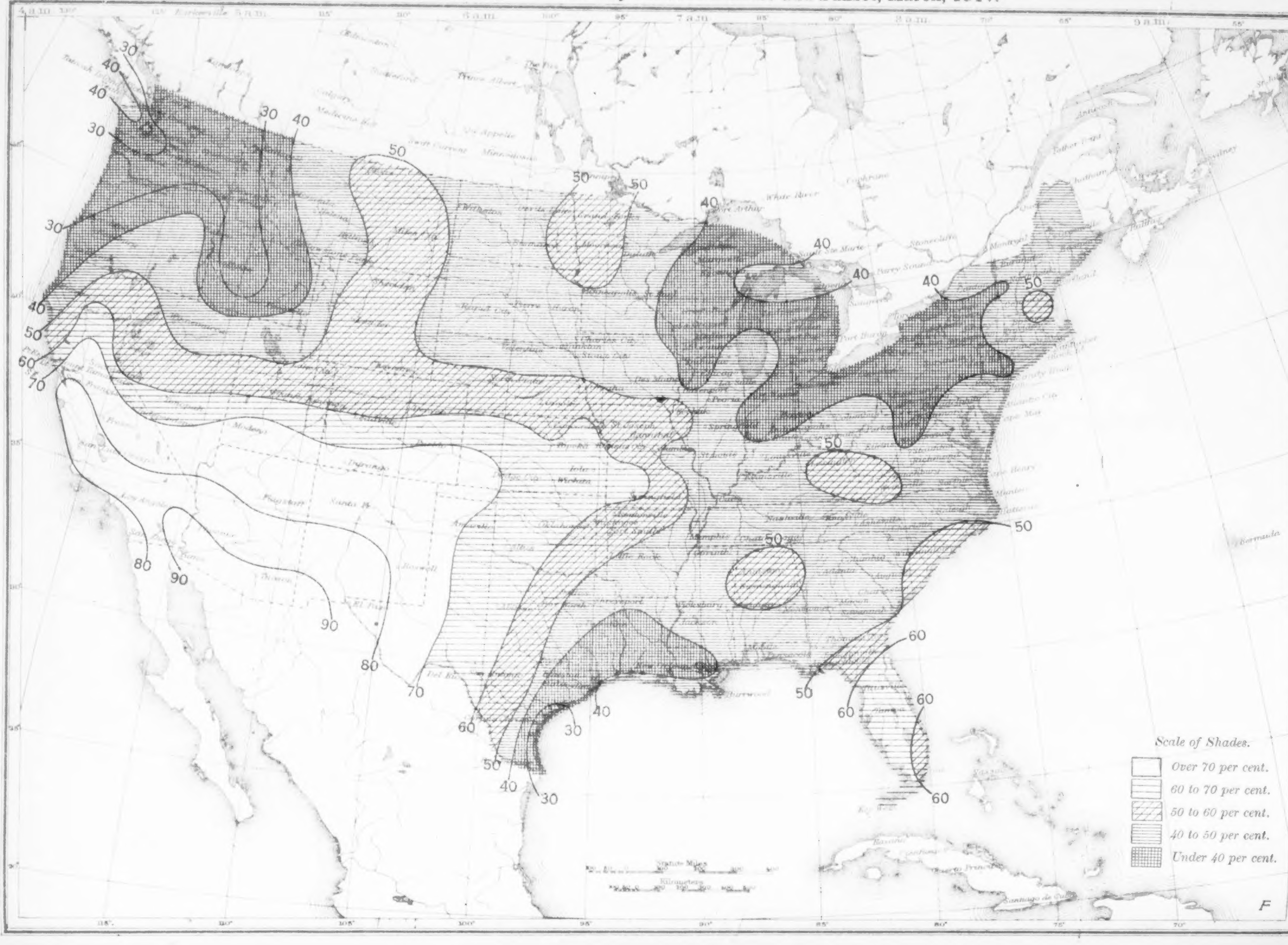


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, March, 1917.

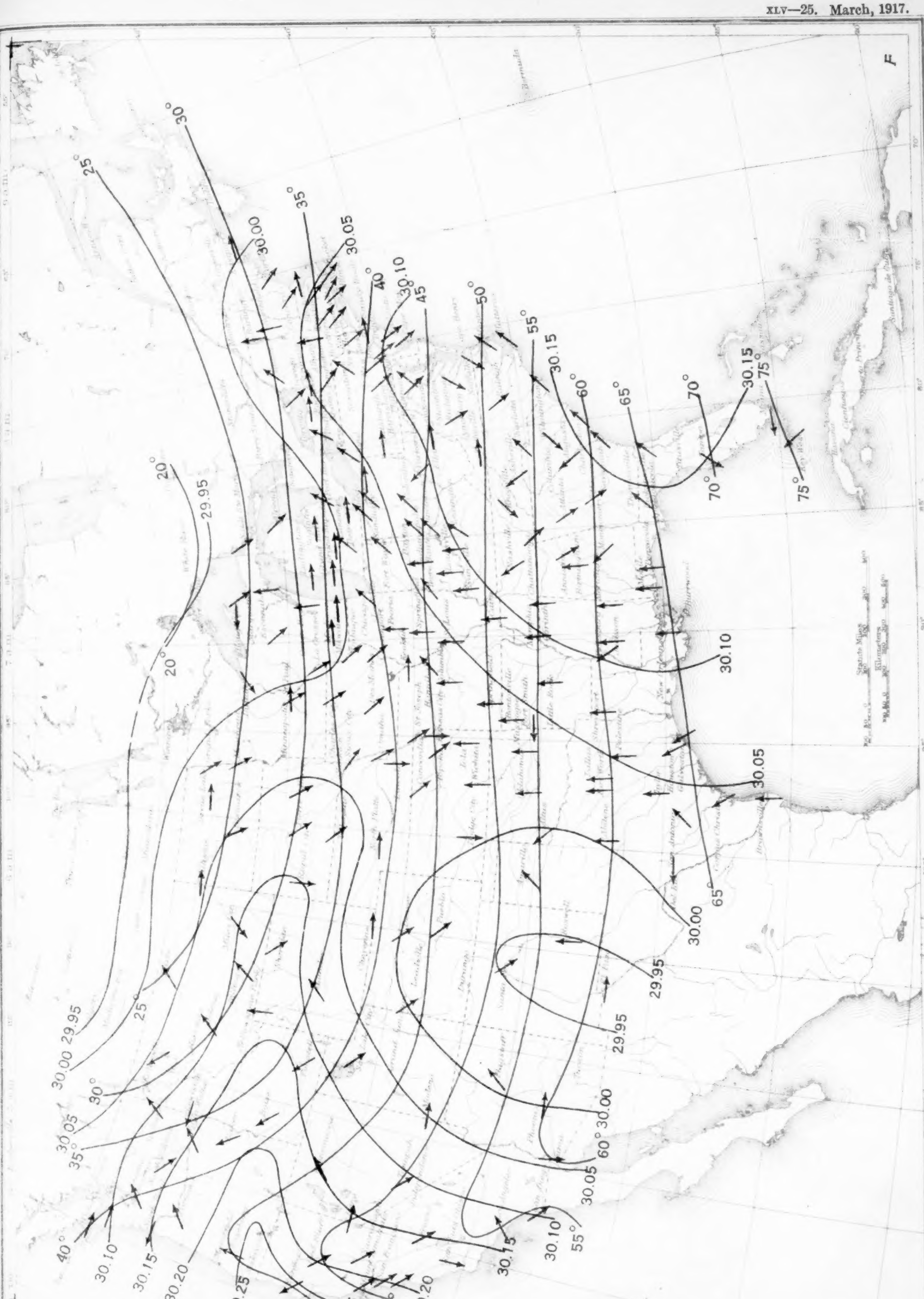


Chart VIII. Total Snowfall, Inches, March, 1917.

Chart IX. Means of Meteorological Data for North Atlantic Ocean, March, 1916.

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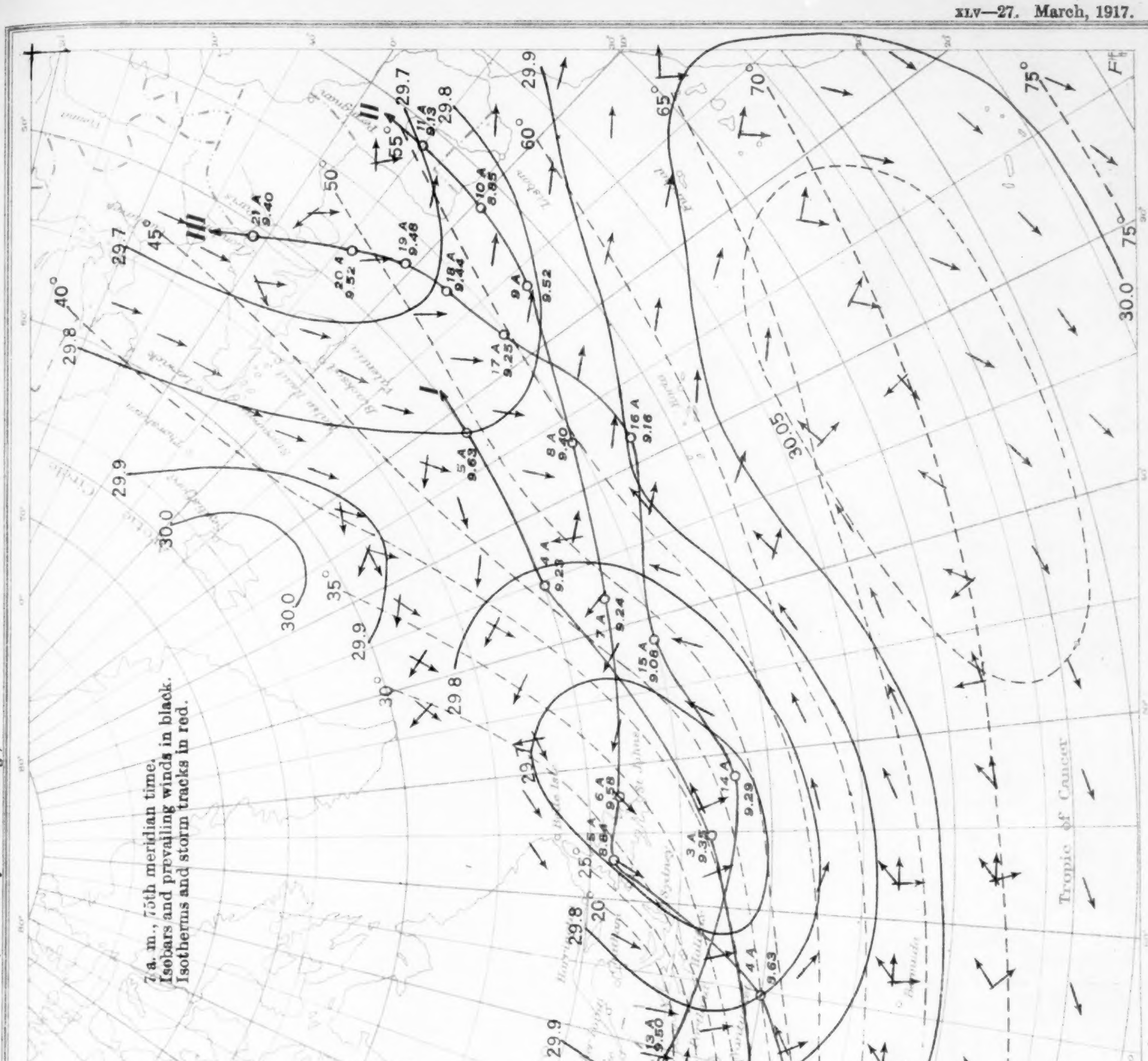
(Plotted by F. A. Young.)



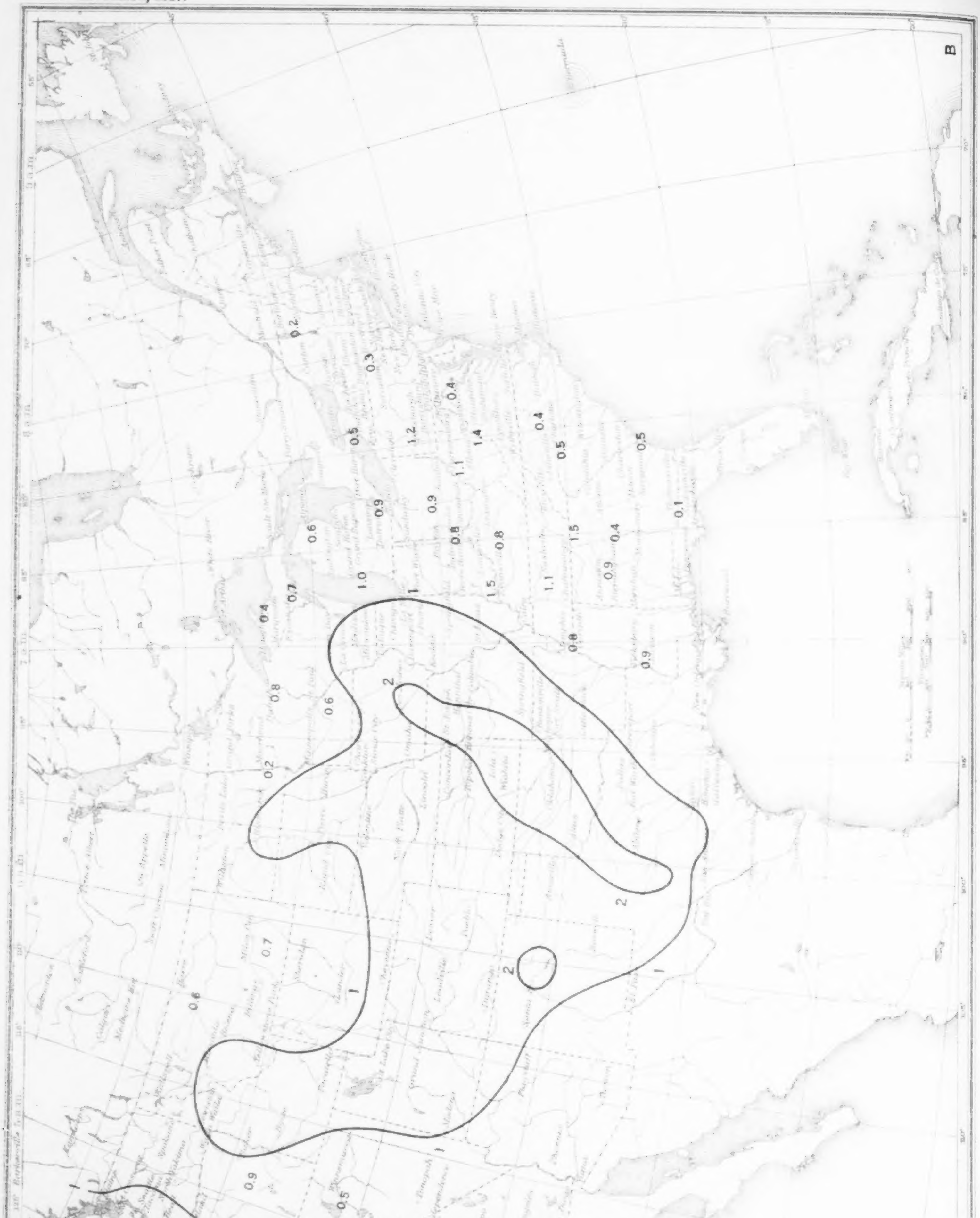


Fig. 1. Average Number of Days with Hail. Spring, 1906-1915.

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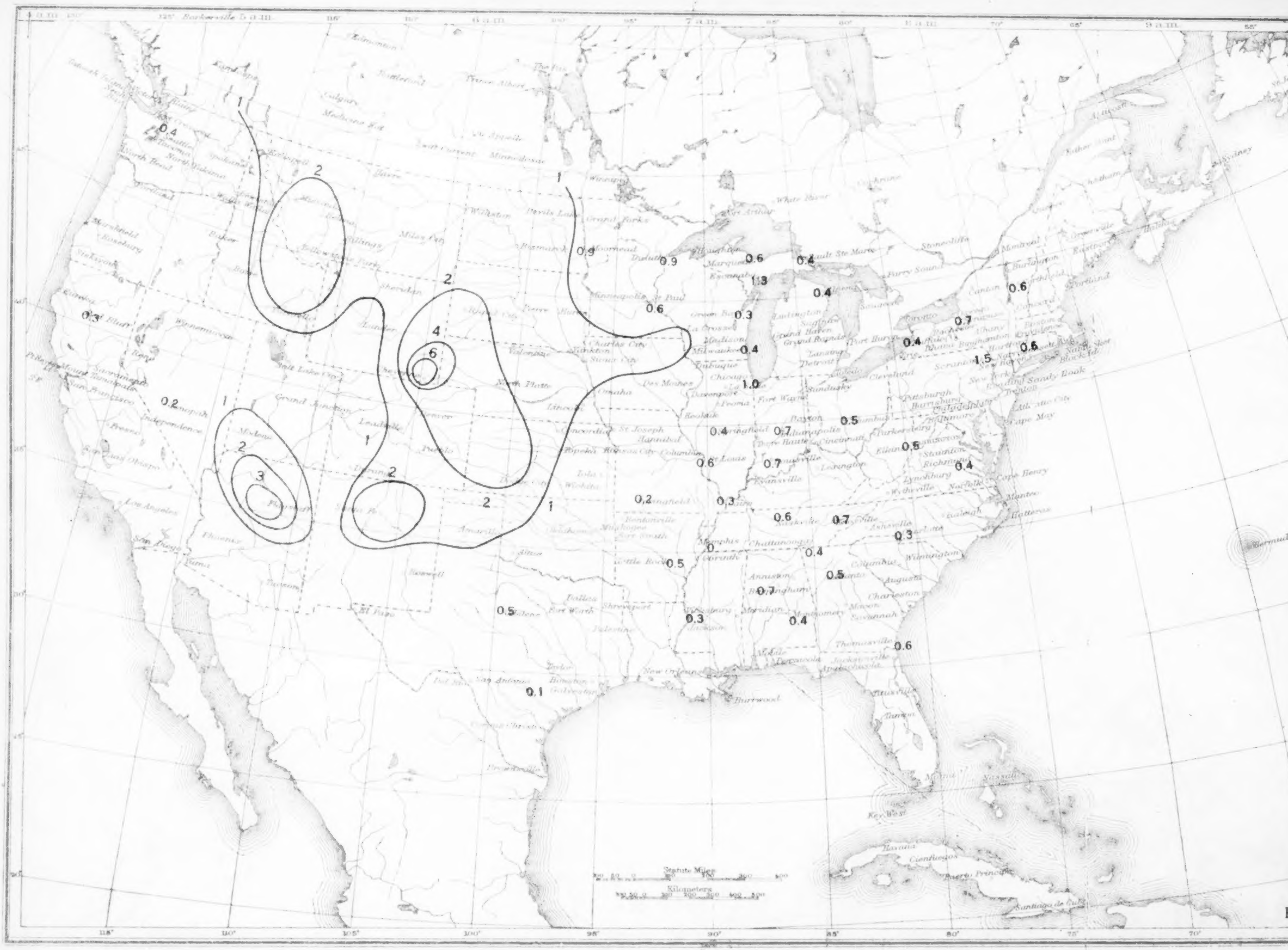

Fig. 2. Average Number of Days with Hail. Summer, 1906-1915.

Fig. 3. Average Number of Days with Hail. Autumn, 1906-1915.

Fig. 3. Average Number of Days with Hail. Autumn, 1906-1915.

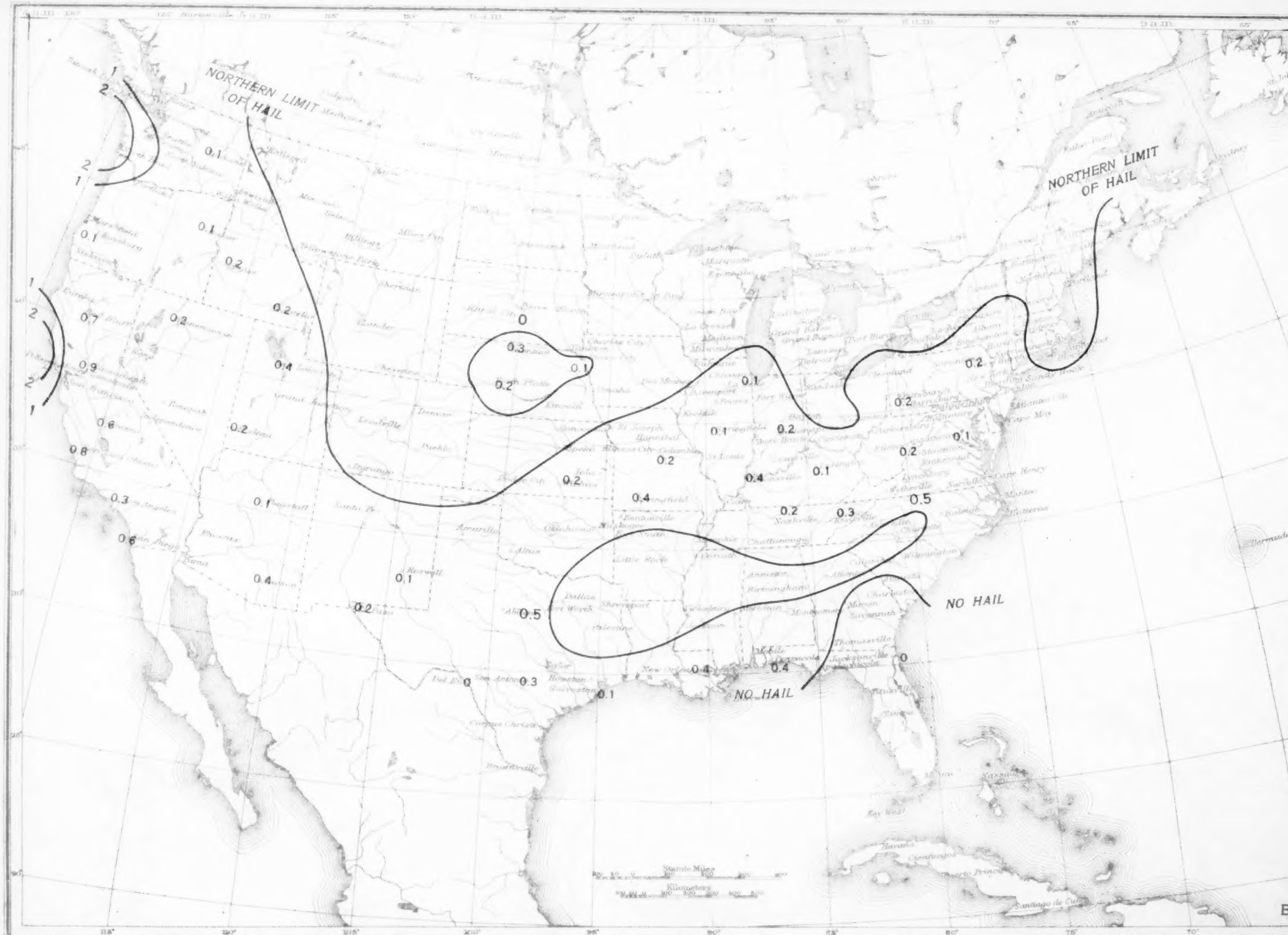

Fig. 4. Average Number of Days with Hail. Winter, 1906-1915.

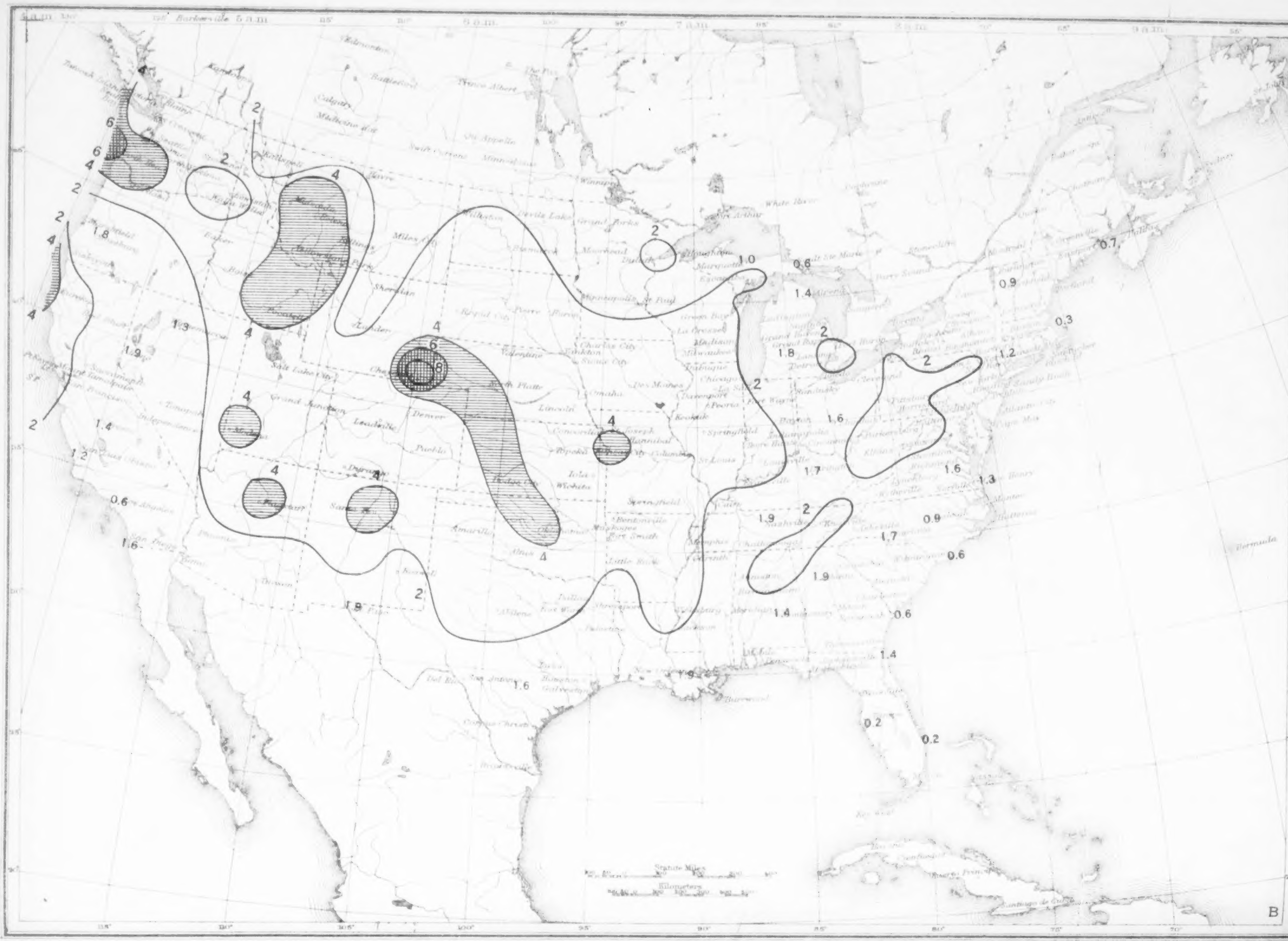

Fig. 5. Average Number of Days with Hail. Year, 1906–1015.

Fig. 5. Average Number of Days with Hail. Year, 1906-1015.